DIGITAL CONTROL AND DATA ACQUISITION SYSTEM FOR TRISONIC WIND TUNNEL OF AERO. ENGG. DEPT. OF I. I. T. K.

By

SQN. LDR. P.C.S. RAUTELA

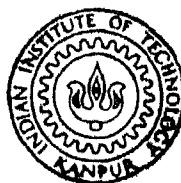**DEPARTMENT OF ELECTRICAL ENGINEERING**
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR
AUGUST, 1978

DIGITAL CONTROL AND DATA ACQUISITION SYSTEM FOR TRISONIC WIND TUNNEL OF AERO. ENGG. DEPT. OF I. I. T. K.

A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
SQN. LDR. P.C.S. RAUTELA

to the
DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR
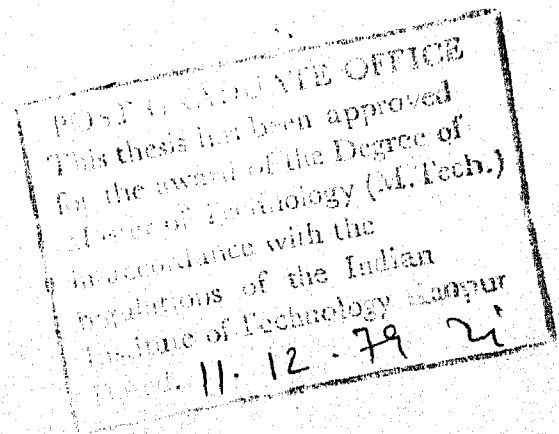AUGUST, 1978

EE-1978-M-RAU-DIG

CERTIFICATE

This is to certify that the thesis entitled, "Digital Control and Data Acquisition System for a Trisonic Wind Tunnel" by Sqn. Ldr. P.C.S. RAUTELA, is a record of work carried out under my supervision and has not been submitted elsewhere for a degree.

Kanpur
30ᵗʰ July   ,1978

H.V. Sahasrabudhe

H.V. Sahasrabudhe
Professor of Computer Science &
Electrical Engineering Department
Indian Institute of Technology
KANPUR

dedicated to the memory of

Late Miss Tokako Imoto

ACKNOWLEDGEMENT

CONTENTS

LIST OF FIGURE

ABSTRACT

This thesis describes the design and implement-
ation of a Digital Data Acquisition and Control System
for the Trisonic Wind Tunnel under installation at the
Aero, Engg. Dept. of I.I.T. Kanpur. The controller
coordinates the various control instruments in the wind
tunnel such as valves, probes, model attitude gear,
optical equipment etc. in real time. It acquires data
from various sources of analog and digital inputs with
respect to control parameters. Provision has been kept
for expansion and improvement of the system for greater
accuracy.

1. INTRODUCTION

The aim of the thesis is to design and implement
a digital data acquisition and control system for the
trisonic wind tunnel automation. The function of this
system is to control various parameters of the wind
tunnel and acquire experimental data all in real time.

1.1 Definition of Process:

A trisonic wind tunnel is under advanced stage of
fabrication at Aero. Engg. Deptt. of I.I.T. Kanpur. The
relevent details of the wind tunnel fabrication have been
given in Fig. 1.1. Till now aeromodels were being tested
on slower,manually operated wind tunnels which limited
the volume and quality of data acquired due to time
criticality of the experiment. The new trisonic wind
tunnel of I.I.T. Kanpur will be the first in the country
to have a computer control and data acquisition which is
based on PDP 11/03. The digital controller controls the
operation of main and regulator valve, probe and model
movement, camera and flash operation. Data is acquired
through fast Analog To Digital Converter and parallel BCD
inputs. The test object is mounted in the tunnel working
space on a support called sting which is given the directional

movement by stepper motor based attitude control gear.
Initially only pitch control is being implemented. The
probe for pressure measurements in tunnel working space
is moved in Y direction by a stepper motor based linear
gear system. In the experiment which lasts for about 20
seconds, measurement of aerodynamic forces on the model
(surface, temperature and pressure in the tunnel working
space and flow pattern observation and photography
through a Schliren optical system is done.

The transducer probe for pressure measurement is
halted to each grid point as defined in the initial para-
meters, its reading is taken through A to D converter and
it is moved to next grid point. The model incidence is
fixed by means of a stepper motor attitude control gear
system for which initial and incremental pitch are defined.
The aerodynamic forces on model surface are measured
through scanivalve assembly. Temperature is measured by
a fixed platinum resister probe through a temperature
module giving BCD output.

1.2 Operation:

The conditions of the experiment are set interactively
by the user by way of defining requisite number of parameters.
These parameters are duration of the experiment, number of

pressure and temperature probe readings, number of camera

snaps   to be taken, initial and incremental pitch. These

details are entered through Decwriter console. The computer

then determines the timing events and pulse sequences.

Thereafter computer checksthe readiness of various sub-

assemblies e.g. amplifiers, power supply, valves, probes etc.

This is followed by amplifier zero offset and calibration,

storing the gain for future reference. Once the system is

ready in   all respects command for opening of main valve

is issued,computer waits for full open indication and issues

command to open the regulator valve. (This valve is

seperately preadjusted to meet the required regulation

using its own control panel). Thereafter a delay of 10

seconds is given to reach steady state flow conditions. Now

our controller starts the programmable clock for its count

down schedule for next event. It takes the first set of

temperature and pressure probe readings (the initial probe

and model position is fixed before the experiment starts).

The camera and flash is energized The probe and model

attitude is now changed to new positions. Now the computer

waits for next time event to take place thereupon the cycle

repeats. The scanivalve is given a command to lock its

ports at the scheduled time. The experiment stops after the

required number of readings in given time frame are over.

Now the scanivalve data is collected through its transducer

multiplexer system. The data collected is in BCD format

for 48 ports. This data and temperature data both of which

are in BCD format are now converted to correct decimal value

and stored. The data after manupulation is stored in a

floppy disc file. At present only single job environment

of Real-time 11 operating system is being used. completed

program is in BASIC which can be easily modified by inserting

the proper line number. Thus flexibility is maintained.
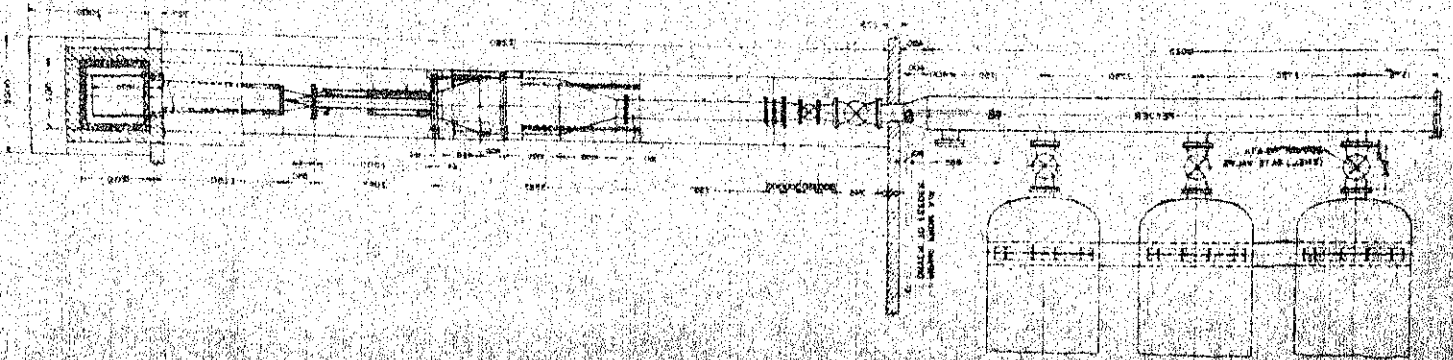
UNIT LAYOUT OF 3'3 X 2'5 BLOWDOWN TRISONIC WIND TUNNEL
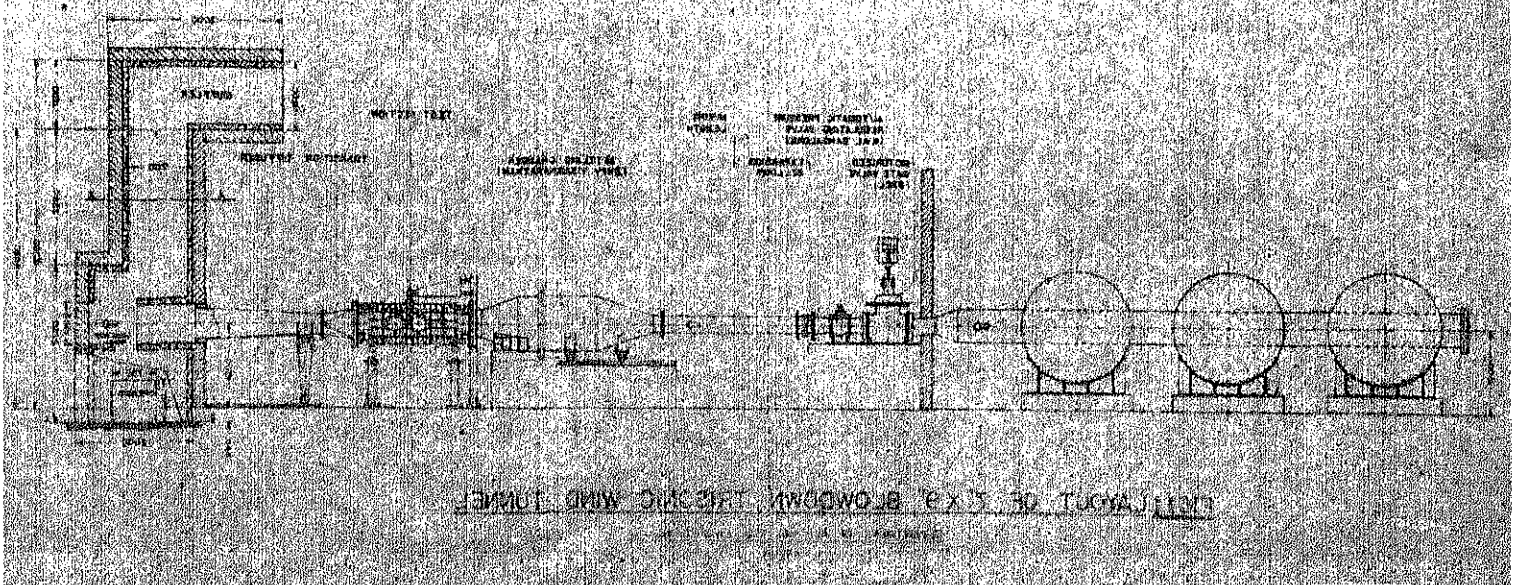
2. COMPUTER & PERIPHERALS SELECTION

The Aero. Engg. Dept. received proposals for computer systems capable of control and data acquisition as listed in Table 2.2. The general critaria for selection were as follows.

2.1 A dedicated Digital (Computer with following facilities.

i) Fast data acquisition up to a maximum of 200 samples per second from digital and analog sources.

ii) Fast Randam access primary memory of at least 16K words and at least 500K of secondary bulk storage memory with access time not acceeding 10 m.s. (track to track).

iii) At least 16 bit digital I/O, minimum 8 channels of analog inputs 0 to $\pm$ 10V with at least 12 bits of resolution.

iv) DMA option and add on module capability for future expansions.

v) Programmable real time clock and at least one level of interrupt facility.

vi) Capability to hook on to larger systems of I.I.T. Kanpur to expand/share resources.

vii) Cheap and realiable I/O device availability with the system.

viii) Higher level language support of Fortran-IV/Basic with Real time operating system.

TABLE 2.2

1	2	3	4	5	6
Proposed System	Word Length	Interrupt	Pr.Memory	Secondary Memory	I/O Device
1. Computer Automation Nacked Milli A-LSI3/0 5E	16 bits	Yes	16K words	512K words	ASR-33 PTR
2. Computer Automation Naked Mini- LSI-2/20	"	16 level	"	"	"
3. Intel System 80/20 Microcomputer	8 bits	8 level	4K words	"	"
4. DEC Lab 11/03 Package minicomputer (LSI 11/03)	16 bits	1 level	16K words MOS	"	"
5. HP 3052 A-Automatic data Acquisision system with 3437A voltmeter scanner 3455A Digital voltage 9825A calculator	—	—	7K	250K casset	Calculator console & character printer
6. HP 3050B - Automatic data acquision system with 3495A voltage scanner 3490A Digital Multimeter 8390A Programmable calculator	—	—	7K	"	TTY & PTR

TABLE 2.2   contd.

	7	8	9	10
Proposed System	Programmable clock	Options	Language and O/S	Remarks
1. Computer Automation Nacked Milli A-LSI3/0 5E	Yes	DMA DI/O A/D D/A	BASIC Fortran IV Real Time O/S	
2. Computer Automation Naked Mini- LSI-2/20	Yest up to 10 KHz	16 bit Digi- tal I/O, 32 bit Relays.	"	
3. Intel System 80/20 Microcomputer	Interval/ event counter Two.	Synchronous/ Asynchronous interface, Serial I/0- Parallel I/0-48, A/D-42 bits	PL/M	
4. DEC Lab 11/03 Package mini- computer (LSI 11/03)	Yes upto 10 MHz	ADC 12 bits DAC 16 bit parallel I/O, DMA 2000 samples per second max. 6000 samples.	BASIC FortranIV APL Real time O/S	EIS, FPIS, Scientific subroutine package & direct hook on compatability to DEC system
5. HP 3052 A-Auto- matic data Acquision system with 3437A voltage scanner 3455A Digital voltmeter 9825A calculator	Digital clock	Buffered I/0 HPIB, Plotter	HPL	Only data acquision system no controls.
6. HP 3050B Automatic data acquision system with 3495A voltage scanner 3490A Digital Multimeter 8390A Programmable calculator	Digital clock	10 channel Relay actuator group	HP Basic	Relay outputs only with data acquisition

ix) Off the shelf compact rigid model to suit
lab applications, no need of special dust filtering,
operating at 230V ±10%, 50 cycles ± 2%, temperature
range up to 100°F.,R.H. 80%.

x) Realiable after sales service with spares support.

xi) Must fit with-in the financial constraints of
Foreign Exchange release.

2.3　A critical evaluation of the proposals in Table 2.1
and their technical summary showed similarity of characteristics
in all systems except proposal no. 5 of HP which was purely
data acquisition system and proposal no. 6 had limited
relay control available. Besides HP systems are calculator
based thus limiting their capability. Dec PDP 11/03 meets
all the critarias of O/S, languages, timing, environmental
and financial constraints. Although similar systems of
proposal no. 1 & 2 were slightly cheaper, the Dec proposal
no. 4 was available in compact Lab package form. Already
about 45 PDP systems are installed in India thus insuring
after sales service and spares availability. It is known
to be realiable system as many such systems are under
use in defence installations who are known for their
environmental specs. It also meets future hook on
capability to proposed Dec 10/90 system of computer centre.

LA-36 is a fast realiable I/O device adjustable from 50 to
300 bauds taking adjustable paper width. pdp 11/03 is LSI
based uses all instruction of pdp 11 family. Its memory
can be expanded and modules can be added on. (Details of
A/D, D/A converters, parallel I/O, clock modules of pdp
11/03 are given in Appendix A, and other hardware in
Chapter 3).

3. DEFINITION OF HARDWARE

This chapter includes details of wind tunnel hardware associated with computer which were designed/fabricated o purchased during the work on this thesis. Relevent IBM-1800 DACS hardware has been briefly touched in Chapter 5 pdp 11/03 hardware details have been given in Appendix A.

3.1 Main Valve (Gate Valve/Isolator Valve)

This valve has been manufactured by BHEL. This valve isolates the high pressure storage tanks from test section (Ref. Fig. 1.1). This valve connects the storage tanks to tunnel working space through a regulator valve. The valve gate is driven by a servo controlled three phase AC motor. Servo system has inputs for remote operation. The valve open/close position is indicated by Torque switches (Ref. Fig. 3.1). The full open/closed indication has been used for giving indication to the computer for relevent flag checks. This is changed to TTL level through nand gates configuration. At present only full open indication has been provided to the parallel I/O DRCSR bit No. 7 for full open sense. Later on when the control console is ready it is proposed to provide the ready flag also for automatic check of the readiness of valve subassembly.(Ref. AP. A Fig. 1.4).
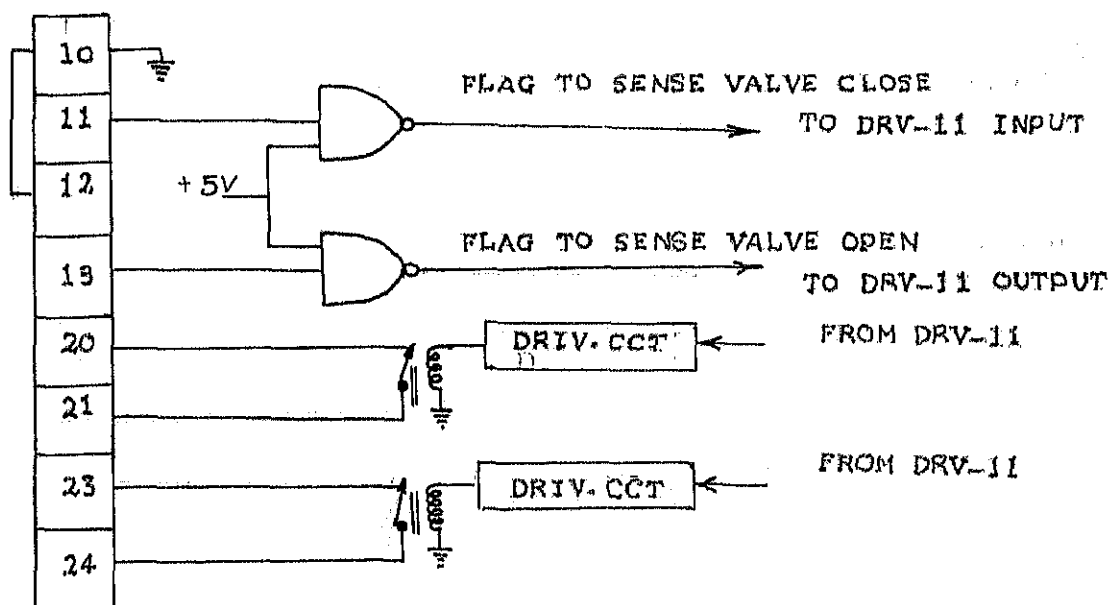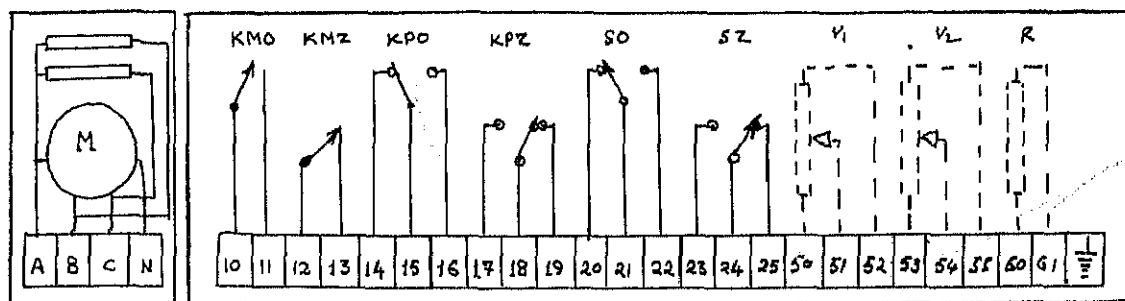
KMO― TORQUE SWITCH FOR POSITION OPEN
KMZ― TORQUE SWITCH FOR POSITION CLOSED
KPO― TERMINAL SWITCH FOR POSITION OPEN
KPZ― TERMINAL SWITCH FOR POSITION CLOSED
SO ―SIGNALLING SWITCH FOR POSITION OPEN
SZ ―SIGNALLING SWITCH FOR POSITION CLOSED
V1,V2―RESISTANCE TRANSMITTER 1/100 OR 2/100 Ω
M ―MOTOR
B ―BRAKE

FIG. 3.1 (XX)   MAIN VALVE INTERNAL WIRING DIGRAM FOR SERVOMOTORS
AND SCHEME TO HOOK ON TO DRV-11 OF PDP 11/03

3.2 Regulater Valve

This valve has been manufactured by NAL with the remote control panel. The valve regulates constant flow of air through tunnel working space during the 20 seconds experiment. The parameters for regulation, permissible error is set at the control panel which has also visual indication to show the current flow and tank pressure. This valve takes 10 seconds for achieving steady state condition of flow for which the software system makes provision. The computer only commands the opening of this valve thereafter complete control is maintained by its own hydrautic regulator system . Ready sense is proposed through nand gating (Fig. 3.1), which will be introduced after the control console is planned.

3.3 Tunnel Working Space:

Tunnel working space is a 7" x 9" section where the test model, temperature and pressure probes are mounted. The temperature probe is permanently fixed to a position. The pressure probe has a transducer which is moved up and down in y direction. The model is mounted on an attitude control gear (only $\pm 18°$ change is attitude permissible from horizontal position due to limited space). The two sides of the tunnel working space are

provided with transparent windows for observation/photo-
graphy and schileren   optical gear. (Ref. Fig. 1.1).

3.4 Scanivalve Subsystem:

The system has been manufactured in USA and assembled
by NAL with provision for signal conditioning and amplifi-
cation. This is a 48 port model for the pressure range
of 0.01 psi to 500 psi. The output is available in
BCD 4 bit format for both the pressure and port number.
It has 24V DC solenoid motor drive 24 ports cutoff valve
(Qty. two) with an autoscan rate of 5 ports/sec. or 2 ports/
sec. or 1 port/sec. Due to this limitation it is proposed
to collect data after the experiment is over.

The scanivalve is a pressure multiplexing system
capable of sequencial scanning of upto 48 unknown pressures
using a single high precision pressure transducer. The
multiplexing system was developed to save the cost of
multiple transducers (each $ 400).

The system consists of a pressure multiplexing unit,
a multiplexer control unit, a digital voltmeter and
optional digital printer. The pressure multiplexer unit
is capable of remote control which is proposed to be done
by the digital controller. The unknown pressures are
connected to the system through the pneumatic input pipes.

WIND →

RANGE CAL PORT
ZERO CAL PORT

P_1 P_2 P_3 P_4 P_5 P_6 P_7 P_8 P_9 P_X

FROM TUNNEL STATIC PRESSURE
FROM TUNNEL TOTAL PRESSURE

TO DATA RECORDER ←

RANGE
ZERO

PRESSURE INLETS

PORT 1 TO 24

PORT 25 TO 48

CUTOFF VALVE 1

CUTOFF VALVE 2

SOLENOID VALVE DRIVE

SOLENOID VALVE DRIVE

SCANIVALVE

PORT IDENTIFICATION ENCODER

PORT IDENTIFICATION DISPLAY

BCD OUT

P-TRANSDUCER POWER SUPPLY

230V 50 √∟

PRESSURE TRANSDUCER

SOLENOID DRIVE

DVM

H-P PRINTER

230V 50√∟

BCD OUTPUT TO COMPUTER DIO. 15/13 BIT

SOLENOID DRIVE SWITCH

SOLENOID DRIVE SWITCH

CUT-OFF VALVE ON/OFF COMMAND

SCANIVALVE DRIVE CONTROLLER

PRINT COMMAND
AUTO/MAN.
HOME CCT & POWER SUPPLY

↑ 230V 50√∟

FIG 3.2   SCHEMATIC CIRCUIT DIGRAM OF 48 PORT PRESSURE
MULTIPLEXING (SCANIVALVE) SUB SYSTEM

These inputs are internally plumbed to two cutoff valves
which are 24 way on/off pneumatic valves. The outputs of
the cutoff valves are connected to 48 storage volumes for
pressure trapping. The other end of these volumes are
connected to scanivalve. These storage cylinders are
scanned one by one by the pressure transducer fitted in the
static assembly giving proportional electrical output. The
electrical output is through a bridge, it is conditioned,
amplified and displayed on the DVM. Both pressure and port
identification are available in BCD format which are being
interfaced to the input buffer of DRV-11, 16 line input.
The DVM can also be switched on to read transducer excitation
voltage for accurate calibration. All necessary control signals
are generated in the system (Ref. Fig. 3.2 & 3.5).

3.5 <u>Temperature Sense Subsystem</u>:

This is a dedicated subsystem of Camare Electronics
England . This system uses a platinum wire resistance of
100 .Ω for sensing change in temperature. The unit is
calibrated at 0°C standard. The subassembly except the
element is being imported from the manufacturers. The unit
consists of a regulated precision DC power supply source for
element excitation, balance bridge, signal conditioner,
amplifier and display unit. It has the option for BCD -
4 digit +Ve logic output format. This output is being

connected to DRINBUF of DRV-11 for acquisition purposes.
The controller issues a hold signal to this unit while
the data is being acquired by the computer to avoid change of
reading. The unit gives an accuracy of $\pm.1^\circ C$ with $.1^\circ C$
resolution with a reading rate of 5 readings/second. It
also provides sign indication.

3.6 Camera/Flash Subsystem:

For provision of observation and photography the tunnel
working space has been provided with two sides of trans-
parent windows. The schileren optical system arranges
for the illumination of the model, reflection of a coherent
light beam. The reflection of the object can be seen on the
glazed glass window screen, The photograph of the test model
and flow pattern can be taken at scheduled intervals.
Cannon F.1 camera with motor drive mainframe has been
selected for automated photography. This is a 35 mm single
reflex focal plane shutter camera (1 to $\frac{1}{2000}$ of second
speed). The main frame motor drive has been added to
facilitate rapid advance of the film enabling 3.5 frames/
second exposure. The unit is self contained for power. It
provides facility for remote control through its timing
unit which has been derived through computer output. The

The remote input has been connected to OUTBUF of DRV-11 to bit No. 15 for camera and bit No. 14 for flash. The required timing pulses which are critical for operation have been generated through software routine. (Ref. Fig. 3.6 & 3.8).
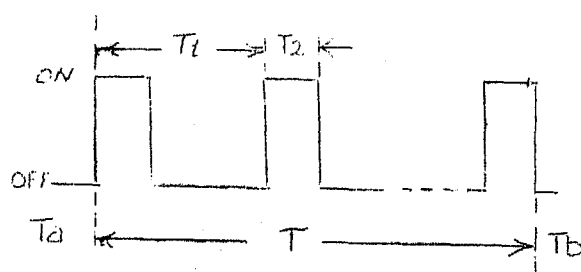
Figure 3.8

Ta   Start time - 'O' ref.

Tb   Stop   time- 20 seconds.

T   Total length of operate
      time -   20 seconds.

T1   Settling time for one
      shot $\frac{1}{3.5}$ seconds.

      Continuous shot line.

3.7 Traverse Gear Probe Subassembly:

This subsystem is used to move the pressure transducer probe up and down along the y axis. (The software has provision for 4 degree of movement freedom). The probe is mounted on the down-stream portion of the tunnel working space. Stepper motor configuration has been utilized for the movement of probe through linear translation gear. Stepper motor has been chosen for easy and precise control through computer generated control pulses. The stepper motor takes 200 steps to make one revolution i.e. 1.8°/step. The

translater has been fabricated and tested with the help of control signals from IBM-1800 based program. The digital controller generates a train of pulses of required width at scheduled timing intervals through its digital output module. This is fed to the motor controller. The speed of the motor and direction can be altered with-out hardware intervention. One bit output i.e. bit 01 of OUTBUF has been kept for direction control ('0' for forward and 1 for reverse direction). The bit '0' controls the number of steps to be moved by giving output of the required number of pulses. The two bit output of the computer is fed to a hardware sequence generator which is made of two D flip flops synchronously clocked. The Q_1, $\bar{Q}_1$ and Q_2, $\bar{Q}_2$ outputs are fed to driver stage before applying to the motor winding. During trial it was found, for smooth hunt free operation of motor a pulse of 9 ms with 3 ms difference between two successive pulses is required. (This test was done for a 100 step motor). Details of the circuits and pulse configuration is given in Fig. 3.6 and Fig. 3.7.

The input from the probe transducer balance bridge is given to signal conditioner and instrumentation amplifier for direct input to A/D converters of pdp 11/03. The amplifier is calibrated before the start of the experiment and its zero offset is set. All ICs have been used (Ref. Fig. 3.4 and 7.7).
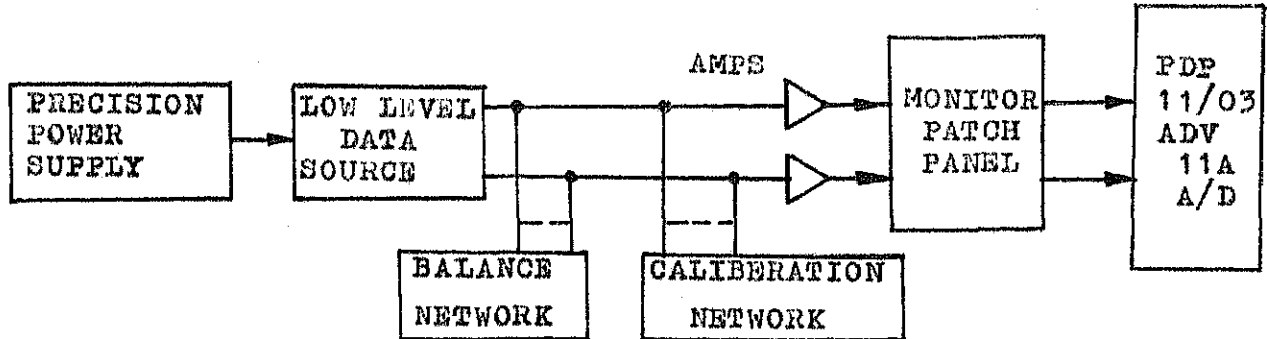
Fig. 33 ANALOG DATA SUB SYS BLOCK DIG
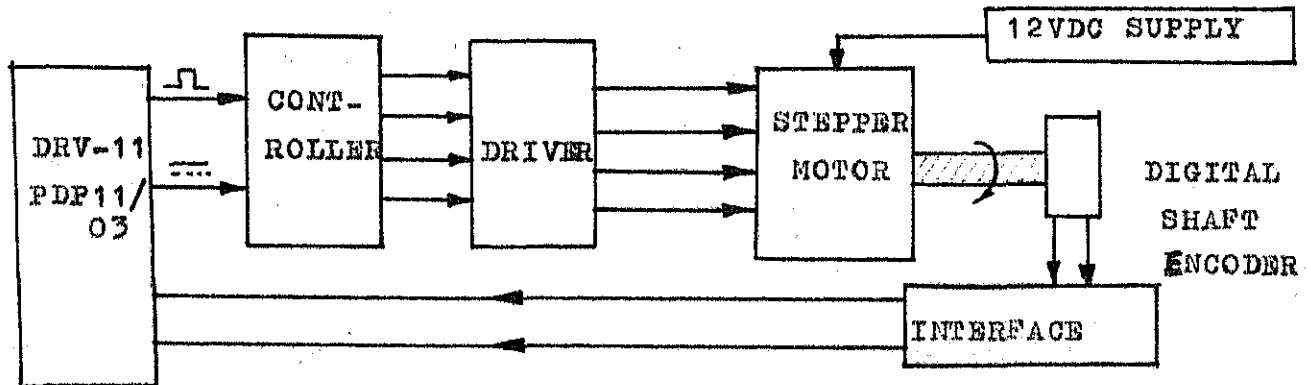
Fig 34 STEPPER MOTOR DRIVE SUB SYSTEM BLOCK DIG
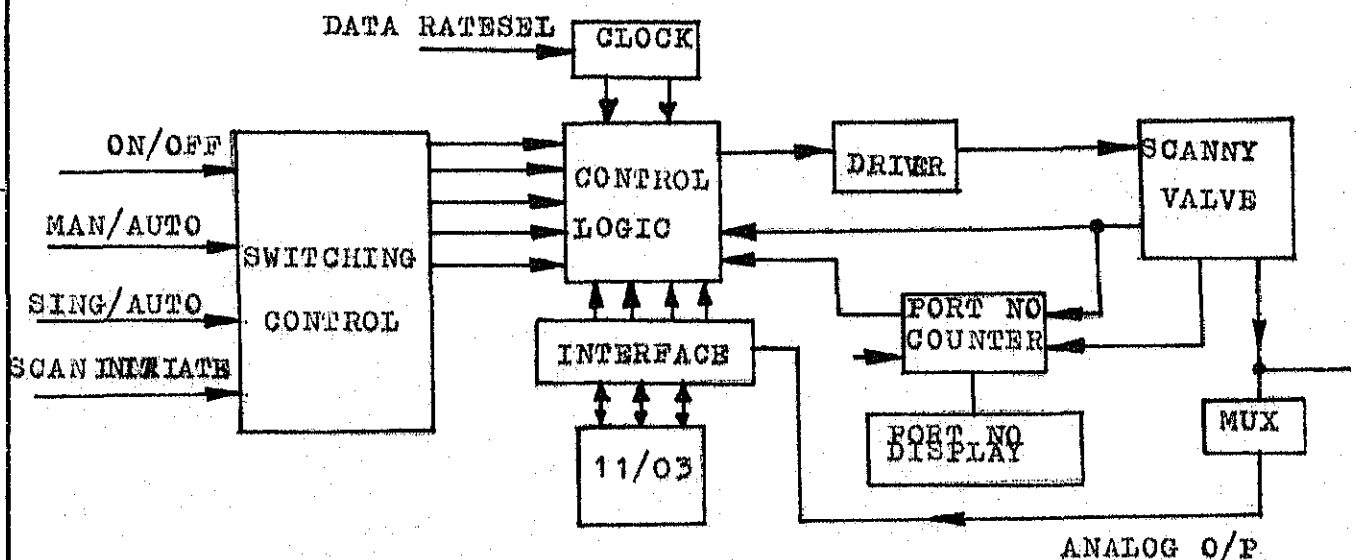
Fig 35 SCANNY VALVE SUB SYS BLOCK DIAGRAM
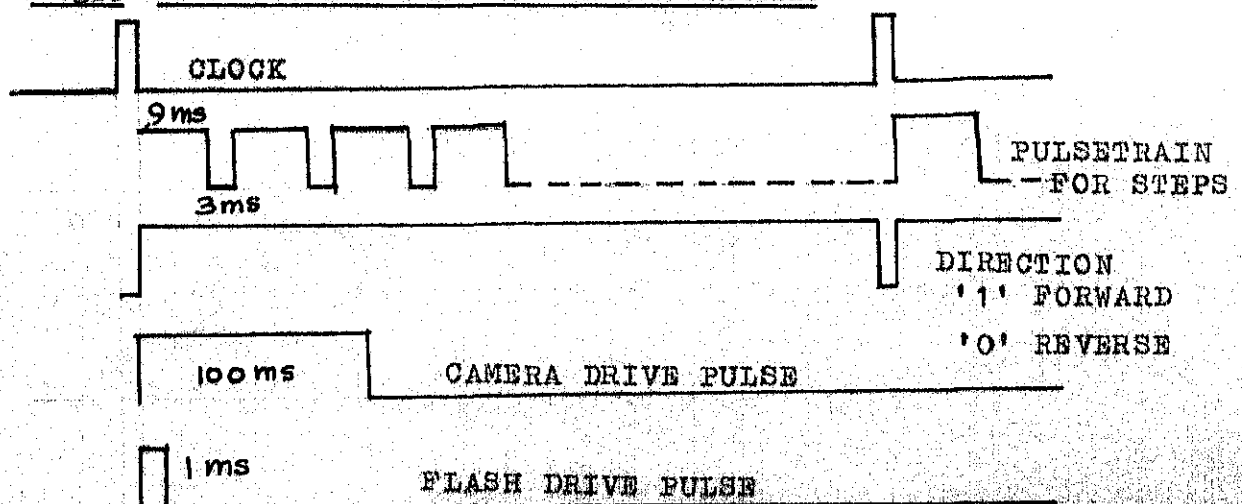
Fig 36 PULSE FOR MOTOR CONTROLLER CAMERA, FLASH

CLOCK → SEQUENCE GEN. → DRIVER STAGE → MOTOR

DIR →

+12V

CLOCK → SEQ. GEN. → Q_1, $\bar{Q}_1$, Q_2, $\bar{Q}_2$

DIR →

+5V   2N995   330Ω   BCN149   +12V

+5V

CLK FROM PdP11/03

+5V   D2   +5V

Q_2 $\bar{Q}_2$

14 13 12 11 10 9 8   14 13 12 11 10 9 8

+Vcc   7486   +Vcc CLR D2 CLK Ps Q_2 $\bar{Q}_2$

7474

1 2 3 4 5 6 7   CLR D1 CLK Ps Q_1 $\bar{Q}_1$

1 2 3 4 5 6 7

$\bar{Q}_1$ D1

DIRECTION
FROM PdP11/03

CLK FROM PdP11/03

Q_1 $\bar{Q}_1$

$D_1 = DIR \oplus \bar{Q}_2$

$D_2 = DIR \oplus Q_1$

DIR=1
↻

DIR=0
↺

Q_1	Q_2
0	0
0	1
1	1
1	0
0	0
0	1
1	1
1	0

CLK

Q_2

Q_1

FIG 3.7   STEPPER MOTOR CONTROLLER

3.8 Model Attitude Control Gear:

The test model is mounted on a support controlled
by model attitude control gear. This gear system is designed
to change the pitch of the model aircraft. The model is
given an initial pitch and is moved to next pitch point as
defined by a parameter of incremental pitch. Due to limited
space of 7" x 9" tunnel a maximum movement of 10 steps in
either direction of horizontal reference line has been
restricted. Earlier it was proposed to use a heavy duty
A/C motor controlled through Analog O/P of computer but with
the availability of higher Torque stepper motor the later
has been selected. This becomes necessary due to high
aerodynamic forces on model surface. A reduction gear
further will give 10 times more Torque output at model control
gear. The drive and control circuit for stepper motor
remains the same. DROUTBUF bit No. 7 and 6 have been
allotted for directional and step control of the motor
respectively.

3.9 Digital I/O Interface to pdp 11/03:

This is used to give outputs to control camera/
flash, operation of valves, operation of stepper motors
for probe and model attitude gear. It is used for input
of data from flags, BCD output from transducers. (Ref.
Appendix A).

3.10 Analog I/P Interface to pdp 11/03:

This is used to sense the transducer input from pressure probe. It is dealt in Appendix A.

3.11 Multiplex Card for Digital Input:

This card has been fabricated using DM 74157 Quad 2 line to 1 line data selector chip. Thus 4 chips are used to control 16 bit input to DRV 11, from 32 data input lines of temperature probe, flags and scanivalve. Two bits (04 & 05) have been earmarked for the control of this card which will need expansion to 64 to 16 line selector with the inclusion of flag checks for readiness of subassemblies.

It is proposed to introduce (Ref. Fig. 1.3 Appendix A) automatic flag checks for subsystem readiness at a later stage. The flags will be set for all subsystems and one bit will be allotted for each flag to be input to DRV 11 input buffer through multiplexer card. This will replace present man-machine dialogue on servicability.(Also Ref. Fig. 1.4 Appendix A).
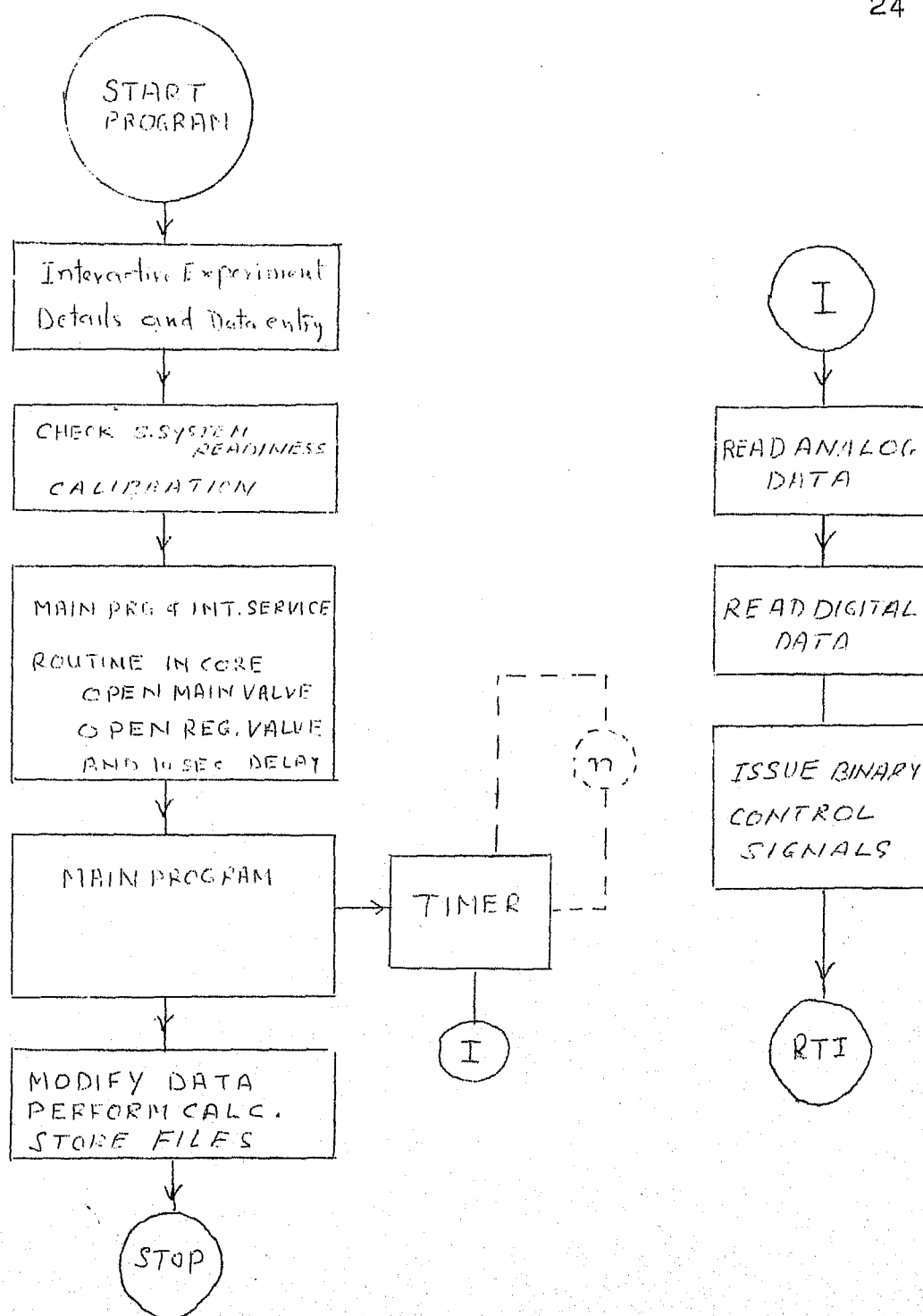
FIG 4.1

4. SOFTWARE DESIGN

The software design is based on the programmable clock event generation capability. The timing event is taken as a reference point to start the sequence of readings and control outputs. After the regulator valve is given control signal to open there is a 10 seconds delay for stablization of flow conditions in tunnel working space. Immediately following this the buffer of the programmable clock is filled with an integer number a multiple of N1/N2 (Total time of experiment/number of readings of probe). The clock starts a count down of this number to present the next event for reference. In the mean time 1st set of readings of probe for pressure and temperature are taken and the probe and aircraft model is moved to next position, now the system waits for the time-event interrupt. On occurance of the interrupt the system performs the task of taking readings and issuing control signals if necessary for scanivalve also and the clock buffer is refilled with this integer number which again starts its count-down schedule for the next event. This process is repeated till the required number of readings have been taken. The interrupt routine in principle must be core resident which does the task of reading the probes and issuing control signals for probe and pitch drive

mechanism. Figure 4./ gives a simplified flow chart of the design. The mainflow chart covering the general characteristics is as per Appendix B, the main features of the flow chart are as follows.

1. Conversation and data entry routine: This routine enters data through console type-writer in the form of man-machine dialogue in question answer form. This has been done with the assumption that the experimenter may not be a computer trained personal. First the date, experiment number, mach number and experimenter's details are entered followed by experiment parameters input of total time of experiment, number of probe readings, no. of snaps to be taken and inctial and incremental pitch. These inputs are stored and based on these the programmable clock is driven for event generation and processor to give appropriate reading and control signals (pulse train). This parameter input part may be replaced by automatic check of thumbwheel switch inputs.

2. Sub-system readiness check routine: This routine is also in the form of man machine dialogue to assertain readiness of all the associated subsystems e.g. DC power supply, scanivalve system, probe and model attitude drive systems, calibration and analog input subsystems, camera and flash

equipment. Provision has also been made to hypass the subsystem not likely to be used in that particular experiment. When the control console is finally designed it is proposed to automate this routine through flag checks. Each subassembly shall give a TTL output to the digital input buffer of the computer (known as flag) which will be automatically scanned for its asserted level. (Ref. Fig. 1.3 Appendix A). Any bit not set will be reported on the console to check if the subsystem is required to be hypassed.

3. Calibration routine: This routine is again in interactive form which outlines the procedure for setting zero offset and calibration. It issues instructions to connect precision reference voltage at the amplifier input to calculate gain for later reference while reading the input through computer A/D converter. This routine also may be automated through the use of relay selectable voltage references for which bits are available on Digital output buffer.

4. System readiness check routine: This routine again checks the system readiness as one unit and issues control signals to bring probe and model to initial position. This is to fix the initial positions for the first set of readings.

5. <u>Start routine</u>:   This routine gives the control signal
to the main valve to open its port and checks for its
full open sense flag. When the full open sense flag is
set it issues control signals to switch on the regulator,
valve, thereafter it starts the clock to count for 10
seconds to give stablization delay. On expiry of the 10
seconds delay period the programmable clock is instructed to
start its count schedule while the set of readings and
control signals to fix the new positions are issued.

6. <u>Traverse gear control routine</u>:   This routine derives
its input in the form of number of steps to be moved/reading
(number of steps = 200/Number of total probe readings to be
taken). The routine generates through software a sequence
of pulses for the required number of steps to be moved along
with direction control (bit asserted zero for forward and
1 for reverse direction). The output of sequence of pulses
and direction control is given to the stepper motor controller
hardware.

7. <u>Model attitude control gear</u>/: routine This routine is similar
to number 6 above. It derives its control parameters of
initial and incremental pitch through conversation routine.
The task of this routine is to allign the test model to
the required attitude as defined in experimental
parameters.

8. Analog data input routine: This routines defines the
analog input channel number and the variable to which the
collected data must be assigned. The routine takes the
analog input from the pressure probe and stores it for
future reference.

9. Programmable clock routine: The input to the routine is
defined by the duration of the experiment and number of
maximum probe readings to be taken. The clock buffer is
filled by an integer number proportional to the time event
and crystal frequency. The clock generates an interrupt
when the count down is over. It is either called by
itself through the routine or fills up the buffer again
and starts the count down schedule by itself for next event.
In case of IBM 1800 the timer calls itself while in case
of pdp 11/03 this is automatically done by mode selection.

10. Camera/flash routine: This routine determines the
requirement for camera/flash operation as defind   by
experimental parameters. It checks the counter flag for
its turn and issues required control signal for the activation
of camera and flash through digital output buffer through
two bits allotted for this purpose. The camera operation
needs a pulse of 100 ms width and the flash of 10 ms
width which are software generated. The camera takes a
snap & moves the film to next frame for exposure.

11. Scanivalve routine: This routine checks for the time
event when a control signal must be issued to lock the
ports. Once the ports are locked this routine is called
again after the experiment is over to collect the BCD
data from the ports and store the same in the array.

12. Temperature routine: This routine checks the time
event for taking the temperature reading. It issues a
temperature hold command and takes the probe reading and
then clears the hold so that the module can sense the new
temperature. The data in BCD format is kept in an array.

13. Data correction routine: Here the collected BCD data
from the arrays of pressure and temperature probe are taken
and   converted to correct decimal value for storage.
The IBM-1800 DACS is discussed in Chapter 5. The pdp 11/03
DACS is discussed in Chapter 6. Both the software
implementations are dependent on the above logic.

5. IMPLEMENTATION DETAILS IBM-1800

This chapter describes details of IBM-1800 TSX
operating system and DACS implementation details which were
used to demonstrate the feasibility of the concept.

5.1 IBM-1800 Time Sharing Executive System(TSX)(Ref.1800-36-pp 1-2):

Real time applications have two chief characteristics
(i) continued on line communication with some external
process (ii) necessity to keep pace with associated process
in operation. The TSX operating system takes care of these
two problems. It acquires data from both on line and off line
tasks with the help of foreground and background environment
operation. It has essentially two parts

    i) Skeleton executive
   ii) non process monitor

The skeleton executive process control and data acquisition
application are serviced in the on-line mode while the
non-process monitor operares in time shared/independent off
line mode. The background job is done when foreground
relinguishes control. The minimum configuration for TSX is
a processor with at least 8K primarymemory, secondary
disk memory, keyboard and CR.

5.1.1 <u>Modes of operation</u>(Ref. 1800-36- pp 37)

In a real time process the computer must rapidly respond to
the signals by conveying some output to the process. TSX
in this mode operates under skeleton executive. Here the
operation can be monitored/controlled by user   written
program. The process may be shared between process and
non-process work. All core loads/programs are accessed from
system resident disk pack. In the off line mode the TSX
operates under TASK (temporary assembled skeleton) as
dedicated N.P. monitor system. Typical OFF   line
applications are assemblies, compilation, utility function etc.

5.2 <u>System concept</u>(Ref. 1800-36 pp 3 to 26)

Skeleton executive is the back bone of the system. It
is core resident for real time while other portions of the
system are swapped from the diskas and when required.
(For memory map ref. Fig. 5.1).

Program segementation known as core load is used
to extend use of limited core memory. The skeleton executive
on core is devided as follows:

1. Skeleton I/O
2. Inskel common   common area in skeleton for
   communication among various types of core load
   used in the system.

3. System Director   It directs handling of interrupts, supersises main line core loads execution or programs, services error condition, maintaining interval time & NP monitor.

4. User Written Programs   Frequently used SRS e.g. interrupt service routine, time counts etc.

5.3 Interrupt Handling:

It consists of hardware priority structure, core store data area for each interrupt level and master interrupt control program (MIC) to recognise the source of interrupt and direct its servicing. There are 3 fixed and 24 additional sources of interrupt levels assignable by the user. Each interrupt line is positioned into a table of priority. Request line is activated if no higher priority interrupt servicing is done else it is queued. A unique address associated with the interrupt level is supplied to the system to locate its service routine. For quick service the routine must be included in skeleton at sys. gen. time. The reason that the feasibility could not/be limited to 20 sec. time limit was that the interrupt service routine could not be included in skeleton as due to unability to do sys. gen. for want of the   punch unit.

5.4 <u>Interval timers</u> (Ref. IBM 1800-36 pp. 42-46).

These are used for periodic scheduling to generate
I/O events. The counter is loaded with an integer number
and a program controlled countdown to zero is initiated which
gives an interrupt which can be used to initiate digital
I/O, analog I/O, relay actuation etc.

5.4 <u>Basic concept of DACS in IBM-1800</u>:

The hardware details and configuration of IBM-1800
DACs is given in Fig. 5.3. Each of the functions of digital
I/O, Analog I/O in the DACs is implemented by some disk/core
resident program. In general there is two way data flow
across the process and computer interface through process
I/O hardware which significantly affects the software
requirements. Most important is analog I/O requiring relay
and multiplex devices coupled with multichannel priority
interrupt system.

5.4.1 <u>Analog Process I/O</u>:

A/D converters are used to convert the resultant
analog signal for computer entry to equivalent digital
value. A multiplexer is used to scan. different channels.
Similarly D/A conversion is done vice versa to control the
analog devices. Thus A/D and D/A converter give a digital
computer ability to communicate with process signals and
control equipment.

LOW CORE

SKELETON I/O
INSKEL COMMON
SYSTEM DIRECTOR
USER & TSX SR'S
VARIABLE CORE

HIGH CORE
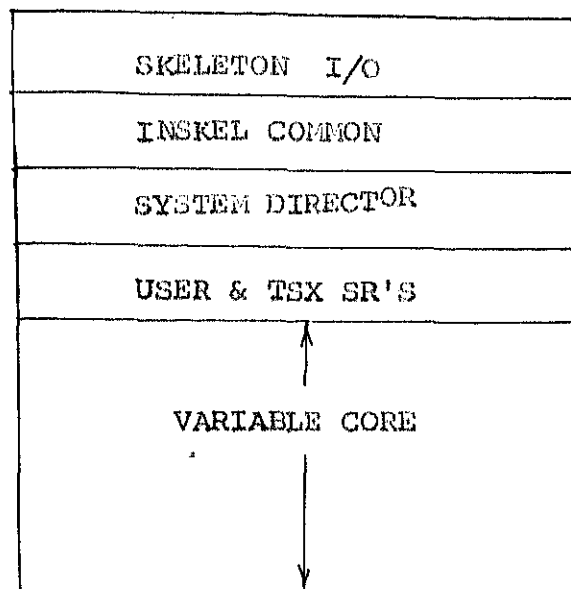
FIG 5.1 MEMORY MAP (SKELETON EXECUTIVE)

TSX

NON PROCESS
SUPERVISER

DISK UTILITY PROGRAM	ASSEMBLER PROGRAM	FORTRAN COMPILER	SIMULATOR PROGRAM

FIG. 5.2 NON PROCESS MONITOR

PROCESS I/O

ANALOG INPUTS

DIGITAL INPUTS

| CONSOLE ENTRY & DISPLAY | | | | | |

MUX

PROCESS INTERPT STATUS	VOLTAGE /CONTACT SENSE	PULSE COUNTER

A/D

A/D CONVERTER

CHANNEL CONTROL

P-&C

IN BUS

OUT BUS

CORE STORAGE

ELECTRON —IC CONTACT OPERATE	O/P PULSES	REGISTER O/P	D/A CONV.

DIGITAL AND ANALOG OUTPUTS
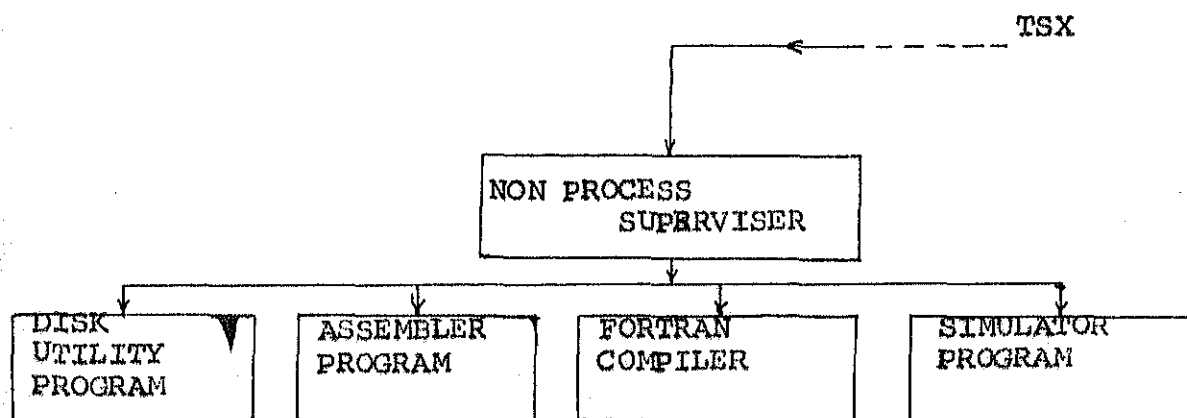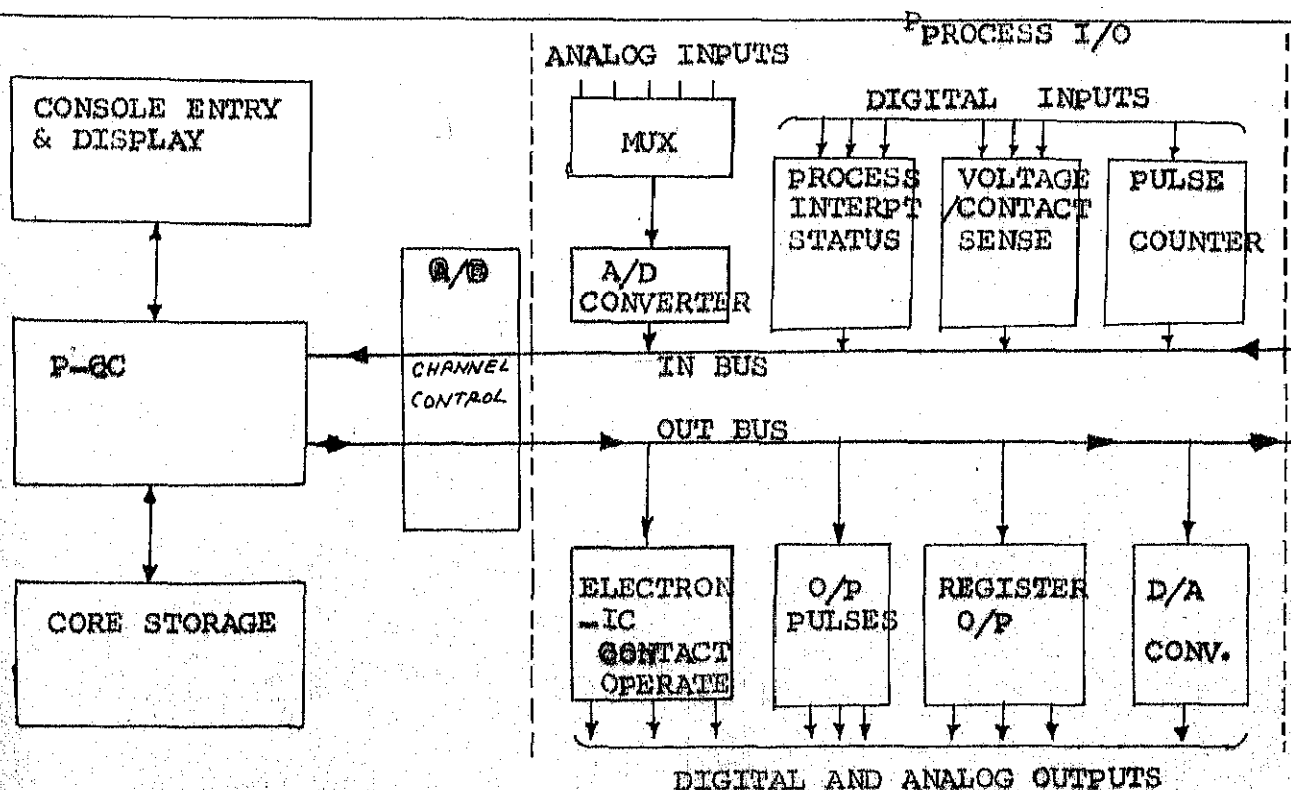
FIG. 5.3 IBM 1800 DACS CONFIGURATION

5.4.2 Digital Process I/O:

These are used for digital signals to control relay operation, give a sequence of pulsed outputs, check flags, input digital data/output digital data to the controlled process. 1800 also provides contact sense and level sense. A process interrupt is like a voltage sense. Digital data can also be read under program control and moved to assigned area by cycle steal.

5.5 Software details:
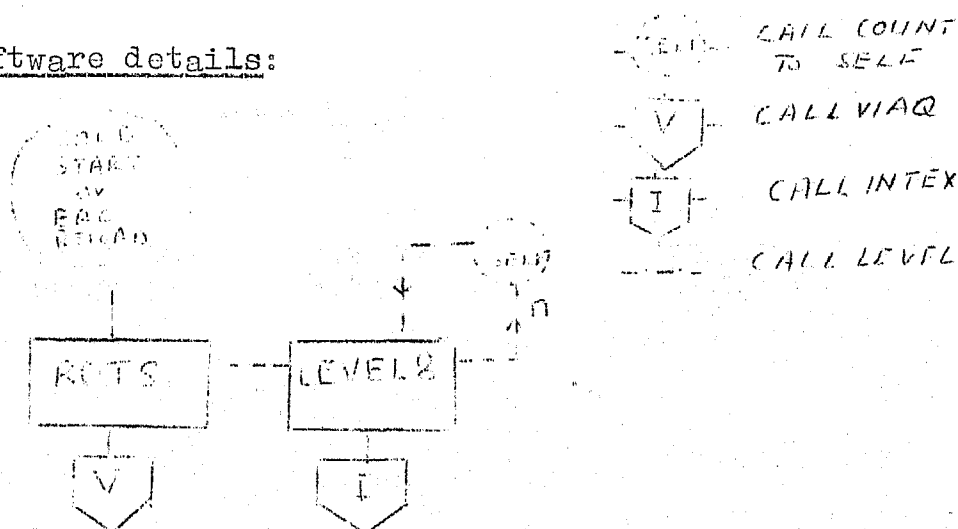
FIG 5.4

Wind tunnel control and data acquisition concept feasibility was demonstrated on IBM-1800 with software written in Fortran IV. The Fortran program is given in Appendix C which is based on general flow chart of Appendix B.

The main program "ROTS" is loaded in to the core by cold start or EAC (Error alert control). ROTS defines initial parameters of the duration of the experiment, number of probe readings and camera snaps. It also defines Table values for pulse output to drive the stepper motors and camera mechanism. It does the task of unmasking, calibration and timer setting. The timer calls "level 8 routine through "Gen" to execute the interrupt routine. Thereafter the timer calls itself to maintain the periodicity till the required number of readings are over when it relinguishes control to main line core load through call INTEX. In the routine certain parameters were assumed e.g. number of readings to be taken from probe. Hence the timing of 20 seconds was not imposed due to problem of sys. gen. The total experiment took 52.4 seconds. The same could be done in 20 seconds by storing the interrupt routine in skeleton. The experiment is dependent on periodic scheduler, to take readings and issue control signals at defined events. The main routines are as follows.

5.5.1 Main Routine "ROTS":

This is the main line core load routine. It reserves common areas for array, flags and counters used by main line core load. It defines files for I/O to reserve space in the

disk. It defines initial table values for digital output/
relay output routines of probe and model attitude gear and
camera. It does unmasking through call UNMK and uses
conversation subroutine, Delay, Calibration and pitch sub-
routines. It does initialization of all tables and sets
probe and model attitude to initial value. It gives 10
seconds delay to regulater valve for stabilization before
the start of the experiment. It starts the clock to note
execution times. It starts timer to start count down for
event interrupt. This is followed by call VIAQ the last
statement of a core load.

5.5.2 Subroutine

This is the initial conversation routine to feed
experimental parameters interactively. This also acesses the
subsystem readiness before the experiment commencement.

5.5.3 Subroutine Delay:

This subroutine is used to give required delay for
the pulse outputs e.g. 9 & 3 ms for stepper motors and
100 & 10 ms. for camera and flash equipment. The subroutine
also gives required number of pulses for the steps to be
moved along with the direction control. The do parameters
were used to establish the correct pulse widths for smooth
operation of the stepper motors. (M & N are the array
parameters).

5.5.4 Subroutine "Gen":

The skeleton contains a timer subroutine for timer 1 which is called by system subroutine call timer, which is given either number 1 or 2 depending on A or B timer. An integer number represents the count valve in the counter. When the count is over this SR Gen. is called which calls **level** 8 interrupt core load which is disk resident in core image format.

5.5.5 Subroutine PIT:

This subroutine does the task of generating the required pulse train for the control of the stepper motor driving the model attitude gear to change the pitch of the aeromodel. It sets the table contents of IDATA and then calls system SR of DO to set the required bit pattern in digital output register. It uses delay SR to give the pulse right width.

5.5.6 Subroutine Cal:

This SR is used for calibration of the amplifier and setting its zero offset. This inturn calls AIP subroutine to define input channel number of the variable where data can be stored. The calibration is done through interactive dialogue. It then stores the gain for future reference.

5.5.7 Level 8 Interrupt core Load "ROTSS":

The interrupt core load "ROTSS" is called through subroutine Gen. on expiry of the timer count. This interrupt core load program is kept in the disk in core image format for quick loading. It uses common areas reserved for communication by "ROTS". It calls system SR DO to communicate to stepper motor drive system of pitch control by using the table values IPOSE, the table values are modified as determined by experiment parameters. Delay SR is used for pulse width control. The probe analog readings are taken through AIP subroutine leaving the value in a variable. The camera and flash are operated through contact operate again by defining table values of IKAM. If the required number of readings is not over the timer is again called to start count, on completion it hands over the control to main line core load through call INTEX.

6. IMPLEMENTATION DETAILS OF PDP 11/03

This chapter describes the real time operating system
of PDP 11/03 called RT-11 and the implementation details
of software.

6.1 RT-11 Operating System:

RT-11 is a disk based single user real time operating
system designed for interactive program development and/or
online application on PDP 11/03 series of DEC. It supports
both single job (SJ) and foreground background (FB) modes
of processing. In addition it does a variety of system and
program development utilities. It also supports Fortran IV,
Basic, Focal and APL higher level languages. It is a device
independent system giving full monitor services e.g. file
management, control of system operating characteristics,
integration of system state and resources and interrupt
servicing. It offers special advantage in lab application
purposes. The I/O system has device handlers as files on
system device.

6.2 Monitor Orginasation:

The optional two monitors of SJ and FB can be used to
users advantage. The FB monitor allows two programs to
operate simultaneously one in the foreground and another

in the background. The foreground job has priority over system resources. Functions which do not need time critical requirements can be developed in the background. Both the monitors have access to system resources. Both can communicate to each other through disk. FB require 4.2K words of core space. The SJ operation needs only 2K words of core. In our application only SJ monitor has been used as /simultaneous processing requirement is not there.

RT-11 monitor is modular in nature so that only these portions actually in use at a given time are core resident. The monitor has 4 major modules plus the device handlers needed for the configuration. Modules are as follows.

(1) RMON (Resident Monitor):- This is the only permanently core resident module occupying 2K words for SJ & 4.2K words for FB in core. It resides at the top of memory. It handles all programmed requests for RT-11 services.

(2) KMON (Keyboard Monitor):- It provides interactive facility between console/and RT-11. Monitor commands allow the user to assign logical names to devices, run programs, load device handlers and control F/B operations. A dot printed by monitor on console is an indication of KB monitors presence. It is swappable and takes 2K words of memory.

(3) USR (User Service Routines)÷ It provides support for
RT-11 file structure. It loads device handlers, opens
files for read or write operation, deletes and renames
files and creates new files, CSI (command string
interpreter) is actually a part of this which can be
accessed by any program to interpret a characteristing
It takes 2K words of memory.

(4) DH (Device Handlers):- These are short routines. These
are merely files on the system device which can be
easily created   by the normal editing and assembling
process. In our system for wind tunnel only the device
handler of Floppy disk (216 words) and console terminal
LA36 (140 words) have been included. These are
swappable.

6.3 General Memory Layout: (Ref. Fig. 6.1 and 6.2)

    The above diagrams give the initial memory layout of
RT-11 on boot strap, it consists of RMON, USR and KMON but
when device handlers are loaded they take place between
RMON and USR pushing USR and KMON down. RT-11 maintains
free memory list to manage memory layout. In SJ,RT-11 allows
the program to be loaded over the KMON and USR if it exceeds
the free memory available. When the program is running the

(EXTERNAL MEMORY) DEVICE REGISTERS — 777777 / 760000

RMON SJ (1.6K): DT, I/O QUEING, USRSWAP R/W PROCESSOR, TTY INT, MON, FUN, EMT, SYS I/O TABLES

USR (2K) SWAPPABLE:- CSB, USR TABLES USR, ERROR HANDLER

KMON 1.5K SWAPPABLE : K.B. FUN COMMAND DISPATCHER, KMON OVERLAY KMON, USR SLIDE ROUTINE

USER SPACE
(CONV. ROUTINE SWAPPABLE)
REST CORE RESIDENT

USER
STACK

577
360

SYS. CORE CONTROL BLOCK

357

DEVICE INT. VECTORS

60

SYS COMMON AREA

57
40

HARDWARE/SOFTWARE
TRAP VECTORS

37

0

Fig.6.1 RT-11 SJ MEMORY LAYOUT

SAME AS SJ

RMON FB (3.3K):- DT, JOB SWITCHING, COM INT, CLK. INT, QUEING, MESG. HD W/R ROUTS, MON, FUNS, EMT. PROC. EMT ERROR BACK G.I. AREA SYS TABS.

FORE GROUND AREA (EXP ROUTINES) CONV. ROUTINE SWAPPABLE

USR (2K) SWAPPABLE : SAME AS SJ FILE ORIENTED FUNS

KMON (1.5K) SWAPPABLE
SAME AS SJ MONITOR

BACK GROUND AREA
(CALCULATION/COMP. ROUTINE) OF EXP.

490

372
360

SYS. CORE CONT BLOCK

357

DEVICE INT VECTORS

60

SYS COMMON AREA

57
40

HARDWARE/SOFTWARE
TRAP VECTORS

37

0

Fig. 6.2 RT-11 FB MEMORY LAYOUT

USR and KMON are not core resident and if required part of
the program is   swapped out to make rooms for USR which
is again swapped out when not required. KMON & USR remain
core resident if enough memory for the program is available.

6.4 Commands :

The operater controls and direct system operation
through three different interfaces. Operater communicate
directly with the monitor using KB commands and special function
keys, communicate indirectly with the monitor or user programs
by issuing an I/O command string. Keyboard commands and
special function keys allow the operator to instruct RT-11
monitor to allocate system resources, manupulate memory
images, start program and use foreground/background services.
RT-11 monitor provides services for program initialization,
control of system operating characteristics, interrogation
of system statusand resources, command interpretation, file
operation, I/O transfer, program transfers and interrupt
servicing. Special features are clock operation, timed wait
etc. All I/O is handled in a block format directly to and
from the user area without intermediate buffering. The queue
manager processes all I/O requests in a normal way. Each
device has a queue. The I/O is done in three modes synchronous,
asynchronous and event driver.

6.5 Timer Support:

With the macro,.MICTIM request the user specified address of a routine is extended for execution after aspecified number of clock ticks. These routines are asynchronous like I/O routines, independent of main program. After the specified time elapses the main program is interrupted, the time completion routin executes and returns control to interrupt program. WAIT (0) is used to wait for interrupt occurance.

6.6 Interrupt Service :

Hardware is elemenated by the use of two program requests for service of interrupt routines to provide necessary link to the monitor I/O system. It allows the use of system stack for interrupt service and allows scheduler to make note of the interrupt. The rest interrupt principle is the same as for IBM-1800. RT 11 provides a set of system programs for macro, edit, expand, assemble, lines, odt, PIP and other utilities. It also provides call and link of an assembly routine through basic Call statement. Extensive use has been made of this facility in this thesis for control and data request statements.

6.7 Software implementation in PDP 11/03
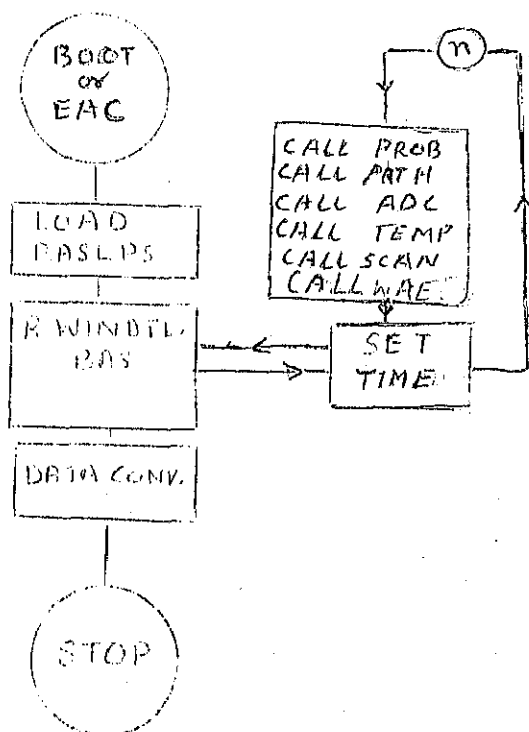
FIG 6.3

The software implementation in PDP 11/03 follows the above logic which is dependent on general software design as per Chapter 4. The program is dependent on a periodic scheduler. The basic program is based on the flow chart of Appendix B where only one dimentional control of probe and pitch has been implemented. The necessity of feedback closed loop control has not been felt due to precise control available on stepper motor positioning. Initially when the PDP 11/03 is booted the resident monitor is brought to the core, then BASLPS /OS is loaded to run the basic WINDTL

BAS experiment program. The experiment is started with a RUN command. The Basic program for control and data acquisition includes the assembly language routines written for control of various parameters linked in BASLPS which can be called by a CALL statement in users program.

6.8 WINDTL.BAS main program:(Ref. Appendix D for program)

The program has been written is basic so that there is no need to have skilled computer personal to run/modefy the program. Statement No. 5 to 160 are the routines meant for interactive operation for input of date, experiment number, mach number and experimenter's name. These are stored.. Statement No. 170 to 340 deal with the input of the experiment parameters of duration of the experiment, number of probe and temperature readings, number of camera shots, initial and incremental pitch. These are again interactively entered through Decwriter console in question answer form. Statement No. 360 to 365 deal with the readiness of subassemblies associated with the experiment. This is also done in question answer form. Provision has been done to bypass the check of subassembly not required for a particular experiment. After the installation this part of the routine will be replaced by automatic flag check routine

for which hardware interface is given in Fig. 6.3. Two
bits to operate MUX. cct. have been reserved, out of which
only one is being used for this routine.

Statement No. 870 to 1040 does the job of calibration of the
amplifier utilized for the pressure transducer probe. The
calibration is done through question answer routines where
connections are   made manually to connect reference voltages
this will finally be replaced by relay operation routine to
do the task automatically only zero offset will have to be
manually set. ADC routine is used to collect data and gain
G is stored for   future reference.

Statement No. 1060 to 1200 checks the final readiness of the
system so that no parameter is by mistake off. Calculation
for this integer value of counter buffer, value of flags
and steps for motors are assigned here.

Statement No. 1300 to 1400 issue the necessary control signal
for the initial position setting of the model attitude and
probe through CALL "PITCH" and CALL "PROB". Now the
environment for the initial settings of the experiment is
set to go ahead with the opening of the valves for air flow.

Statement No. 1600 - 4300 cover the main experiment operation.
First the main valve is issued control signal to open the port
and its full open indication flag is sensed before command to

open the regulator valve is issued followed by 10 seconds delay. This is achieved by CALL "VALV" statement No. 1700 and CALL "SETC" of statement No. 1800. Statement No. 2050 i.e. CALL "SETR" starts the clock to give time event indication determined by experimental parameters N1 & N2.

Statement No. 2300-2350 take the pressure probe reading from channel zero and store the result in the array at A1 through CALL "ADC".

Statement No. 2400-2500 take the temperature probe reading through CALL "TEMP" and store the result in an array A2.

Statement No. 2600-3000 control the camera/flash operation through CALL "CAMR". These determine how many times the camera must be operated during the experiment as defined by initial parameters.

Statement No. 3200 to 4100 control the operation of the stepper motors controlling probe & model attitude gear through CALL "PROB" and CALL "PITH". Here command is also issued at appropriate event for the operation of scanivalve through CALL "SCAN".

Statement No. 4200 makes the process wait for next time event to occur to repeat the process.

Statement No. 4400 to 6000 collect the data from the 48 ports of the scanivalve through CALL "SCAN" and store the same in Array A3. Now the data in 4 bit BCD format is again called from the array and corrected to correct decimal format and stored back in the array A3.

Statement No. 6025 to 7200 do the conversion of the 4 bit BCD data in to decimal, stored in array A2 from temperature sensing module. The corrected value is stored back in array A2.

Statement No. 7300 to 8200 are normal output routines for data in the arrays and the character strings stored for experiment details.

The various CALL statements used in the program are as follows:

CALL "ADC (A,C):- This is a system routine in module 1 to take analog readings. This command initiates the activation of the specified channel A its analog sample taken and return the digital valve in the variable C.

CALL "TEMP"(C) : This routine has been written in assembly language (Ref. Appendix D). It initiates the collection of the binary data available to the input of DRINBUF from the temperature

module by giving a hold signal to it through bit 09 of OUTBUF of DRV-11. In the routine the syntax and arguments are also tested. The final collected value is kept in variable C. Now the hold bit is cleared so that the temperature module could proceed ahead for next reading, DRINBUF=167774, DROUTBUF = 167772.

CALL "VALV" :- This assembly language routine (Ref. Appendix D) had been written for the automation of two valves. First it switches on main valve by setting the bit 12 of DROUTBUF. It now checks for complete open indication through bit 7 of DRCSR, when the same is set, issues command to open the regulator valve by setting bit 13 of DROUTBUF.

CALL "CAMR" :- This assembly language routine (Ref. Appendix D) has been written to operate the camera and flash equipment for photography. The camera is operated by setting bit No. 15 of DROUTBUF for a required width of 100 ms. and the flash through setting of bit No. 14.

CALL "PITH" (A,B):   This assembly language routine (Ref. Appendix D) controls the operation of the stepper motor controlled model attitude control gear assembly. The routine checks the syntax and arguments through Getarg. A is the number of steps to be moved and B is the directional control parameter. Since arguments A&B are stored in two words each this is packed in one word and moved to Reg. R2 & R3. The routine introduces the proper width of the pulse i.e. 9 ms followed by a 3 ns gap between two pulses. The routine for each grid point is called only once which generates complete pulse train. (B is zero for forward and 1 for reverse direction).

CALL "PROB" (A,B):   This assembly language routine (Ref. Appendix D) control the operation of the stepper motor controlling the linear move- ment of the pressure transducer probe in the tunnel working space. The routine is similar in all the respects to CALL "PITH".

CALL "SCAN"(A,C):   This assembly language routine (Ref.
Appendix D) controls the operation of the
scanivalve system. First the syntax and
arguments are checked through Getarg. A
gives an indication of the control   for
locking the ports (A=1) or for data acqui-
sition (A=0) in the relevent cases bit
12 & 11 is set for operation. The value
in the later case is stored in variable C.
This routine will need modeficcation to
include hold command while data is being
acquired, this detail could not be included
due to lack of technical details on
scanivalve.

CALL "SETC"(Time,rate): This is a system routine in module 2:
This controls the operation of programmable
clock the arguement time and rate is to be
specified. The clock status register is
set to rate and will run for time seconds.
On expiry of it a clock interrupt will occur
to do any of the clock controlled function.
The time arguement is calculated a TIME
= time in seconds x clock rate specified.

the clock is run in zero mode for non

repeatation (Ref. PPI-8 of Basic RT-11

manual).

CALL "SETR"(Rate, mode, preset): This system routine governs

the programmable clock by setting the clock

running in specified mode and at desired

rate. The preset is clock counter value. The

interrupt enable is always set. The rate

values are from 0 to 7 defining clock rates of

no rate, 1 MHz, 100 KHz, 10 KHz, 1 KHz, 100

Hz, schmittrigger & line frequence respect-

ively. We have taken this as 2 (i.e. 100 KHz),

Mode value 0 to three define simple interval

mode, repeated interval mode, external event

mode and event timings. We are using mode

0. The buffer preset value has been calcu-

lated as $T = \frac{N1}{N2} \times 100000$ (Ref. pp I-8 of

Basic RT manual).

CALL "WAIT" (N): This system routine disables further program

execution until the specified event "N"

occurs, n=0 for clock over flow, n=1 for

schmitt trigger, n=2 for either of them to

take place.

The use of Getarg is done for syntax and arguements check
of the CALL statement, the STORE SR keeps the value of
register in the variable C. FAC1 & FAC2 are Table addresses
while OUBF, INBF & DRCSR are the DR11 - OUTPUT BUFFER
(Addres 167772), INPUTBUFFER (Address 167774) and control and
state register (Addres 167770) respectively. The above
assembly routine of Appendix D were assembled as FUN4.MAC and
the function table was assembled as FUN3 MAC. FUN3.MAC was
amulgamated into the RT11 function table FTBL.MAC to include
the other routines. Finally ROTS2, was produced by linking
all module as per following procedure.

```
. R MACRO
* FTBL = PERPAR, FTBL
* PERVEC= PERPAR, PERVEC
* RTINT = PERPAR, RTINT
*
. R LINK
* ROTS2=BASICR, FPMP, FTBL1, PERVEC, RTINT, GETARG/C
* FUN4, BASICE, BASICX, LPS0, LPS1, LPS2C, LPS3, LPS4,
  BASICH.
```

ROTS2 has been loaded as BASLPS.SAV in the floppy disk. This
operating system along with WINDTL.BAS, FUN3.MAC & FUN4.MAC
has been copied in a floppy disk (details in Appendix E).
The disk has been given to the users ready to be loaded
on arrival of the system.

7. CONCLUSION

A Digital Controller and Data Acquisition System has been designed for implementation on trisonic wind tunnel system of Aero. Engg. Dept. of I.I.T. Kanpur. The system which is based on DEC micro-computer PDP 11/03 provides complete control of the wind tunnel i.e. operating of main and regulator valve, movement of pressure transducer probe and change of model attitude through attitude control gear, control of scanivalve and temperature sense module. The system acquires data from temperature and scanivalve multiplex system in BCD format and from pressure transducer in analog form. The computer based control and data acquisition system now makes it possible to take complete set of readings on a test model in one experiment itself while exercising precise control on movements thereby eliminating human errors. So far the data acquisition and control was exercised manually therefore it was possible to have few observations only in the 20 seconds duration. The feasibility of the software was first tested on IBM-1800 with successful control of all parameters. The PDP 11/03 routines have been tested for correctness at MOD Delhi computer. The modified RT-11 includes all additional call routines for wind tunnel control. The routines have been transferred to a floppy disk ready to run.

7.1 Future Additions:

The CALL routines have been kept simple & flexible
to include more features if required. Since scanivalve
technical details were not available the CALL "SCAN" routines
will need modification to include more details for hold and
other control signals. These extra routines can be added
to FUN4.MAC before being included to FTBL. The main program
has been written in Basic so that any one can run & modify
the program with insertion of new statement numbers. Although
the requirement of Aero. Engg. was to take maximum 40 readings
of probe during 20 second experiment it can be easily take
up to 400 readings in 20 seconds duration without change of
hardware with little modification of software with parallel
movement control of two stepper motors. With modification
of hardware upto 2000 readings can be easily taken during
this period. Thus enough flexibility is available. Once the
control console is finalised the whole operation can be
automated as suggested in the thesis thus the operater need
not do any thing than the initial conversation. (Ref. Fig.
1.3 and 1.4 of Appendix A).

APPENDIX A

HARDWARE DESCRIPTION OF PDP 11/03 IN BRIEF

Configuration: (Ref. Fig. 1.1). The PDP 11/03 JB system
consists of LSI 11/03 microcomputer with 32 K bytes of MOS
memory, extended arithmatic set and option given in the
proposal of Chapter 2. The KD 11-F Microcomputer module
includes all function chips e.g. processor data chip, processor
microinstruction ROM chip, processor control chip, bus drivers
and receivers, bus I/O control logic, interrupt control and
reset logic, bus arbitration logic and special function.
The clock pulse generator generates 4 non overlapping clocks
for   different functions. It has 402 instructions and
is fully compatable to other DEC series. It has 16 K x 16 bit
dynamic MOS memory which requires refresh operation every
1.6 ms. which is automatically done. Access time is 300 n.s.
DLV 11- Asynchronous Line Interface connects bus to several
communication lines. This module receives serial data from
peripheral devices, assembles it to parallel data and transfer
it to LSI-11 bus. It performs function vice-versa for data
from LSI-11 bus to peripheral devices. It can give Baud
rates of 50 to 9600.

DRV11-Parallel Line Unit: This is a general purpose interface
unit for controlling TTL-DTL devices connected to LSI Bus.

It can support up to 25 feet of cable thus giving us enough
length to carry cables upto control console   It offers
program controlled data transfer at rates up to 44 K words/
second. Data is handled by 16 diode clamped input lines and
16 latched output lines. Device address is selectable. In
our configuration this module controls operation of probe
and model attitude control stepper, motors operation of relays
to operate main & isolator value, control of multiplex
selector of input lines, operation of camera and flash units
and operation and control of scanivalve system and
temperature sensing module. It also accepts inputs from
temperature sensing module and scanivalve pressure sense
multiplex system in 4 bit BCD format. The interfacing to
user devices is done through burg connectors. Its output
interface is a 16 bit buffer DROUTBUF which can be either
loaded or read under program control. Loading of OUTBUF also
generates a New Data Ready 300 n.s. pulse which will be
utilized for scanivalve data collection at a later stage.
The input data interface is also 16 bit called DRINFUF which
comprises of gated bus drivers that transfer data from user
devices on to the LSI-11 bus under program control. DRINBUF
is not capable of storing data. When data has been read it
generates a +ve going Data Transmitted H pulse to inform the
user device that the data has been accepted.

Two request flags Req. A&B can be accessed by user device in DRCSR word. In the CALL "VALV" routine REQ A has been used to sense the full open valve condition of main valve thus saving a bit in DRINBUF. (Ref. Fig. 1.2 for bit allotment and Digital EK-ADV11-OP-002 for details)

ADV11-A Analog To Digital Converter: This is a 12 bit successive - approximation A To D converter with built in multiplexer and sample and hold for use on the LSI-11 bus. It has provision for 16 channel single ended input or 8 channel differential input. A to D conversion is either program controlled or clock over flow controlled or external event controlled, as determined by its control and status regiser (CSR). Digital A/D conversion data is routed through a buffer register to LSI-11 for programmed transfer to memory. It has also the precison output voltage for user test purposes. It is proposed to use this as reference voltage for calibration of amplifiers. Analog input scale range is 10.24 V. Bipolar (-5.12V to +5.12V). The gain and offset error is adjustable to zero. It works in following steps.

1. Enable specified channel
2. Sample the channel
3. Performs A/D conversion
4. Hold the sample
5. when LSB has resolved in successive approximation register (SAR), it transfers SAR contents to Data buffer.

6. Inform process that the job is done
7. Reacquire and Track the programmed channel.

In our system it is being used to acquire data from pressure probe.

AAV-11-A Digital to Analog Converter: This is 4 channel D/A converter module for LSI. It has interface circuitry, 4 D/A converters and voltage references. It has 12 bits of resolution each channel has its holding register which can be seperately addressed. Bit 0-3 of 4th holding register can be used as 4 bit digital output register. The analog output range is $\pm$ 2.5V to $\pm$ 10.24V bipolar 0 to 5.12 V or 0 to 10.24 V unipolar, drive capability $\pm$ 4 mA per converter, slewing speed 5V/μ s. Originally this module was planned to drive the model attitude control motor which has now been replaced by stepper motor for accurate control. Its 4 bit digital output can now be utilized to drive relays.

KWV-11A Programmable Real-Time Clock: This is a programmable real time clock/counter combination providing a variety of means for determining time intervals or counting events. It can be used to generate interupts to LSI-11 processor at predetermined-intervals, to synchronise processor to external events. It can also inetiate A/D conversion. It has a 16 bit resolution and it can be driven by any of the

5 crystal controlled frequencies (100 Hz to 1 MHz) or line
frequency/schmitt trigger. It has 4 programmable modes.
The clock over-flow pulse is 500 ns. wide. Its CSR provides
a means for the processor to control the operation of
KWV11-A and to derive information about its operating
condition. Bits are provided for enabling interrupts, mode
selection, maintenance operation; start of counts and
overflow and Schmitt Trigger event monitoring. Buffer/
preset and counter register is 16 bit read/write register
which can be loaded either under program control or from
the counter as per the mode of operation.

The complete experiment is dependent to this clock
for time event generation for execution. It works on Model
(repeated interval) using 100 KHz crystal.

512 K BYTE FLOPPY

PDP 11/03

DECWRITER LA36

SYSTEM CARD KD11F

DLV 11 SERIAL LINE INTRF.

ADV-11A A/D CON.

EXTRA SLOT

DRV11 PARALLEL LINE UNIT

KWV11A CLOCK

PRESSURE PROBE INPUT

USER SPEC.

O/P TO STEPPER MOTORS, CAMERA, RELAYS, MUX,

I/P FROM TEMP. PROBE SCANIVALVE

APENDIX A Fig. 1.1   PDP 11/03 BASED DATA ACQUISITION AND CONTROL SYSTEM CONFIGURATION

DR OUT BUFFER

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

CAMERA & FLASH

RELAYS REGULAT. & MAIN VALVE

SCANI-VALVE CONTROL

TEMP HOLD

PITCH CONTROL

MUX CONTROL

PROBE CONTROL

DR IN BUFFER

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

I/P FROM MULTIPLEXER, TEMPERATURE IN BCD(4 BIT),
SCANIVALVE INPUT BCD, FLAGS INPUT
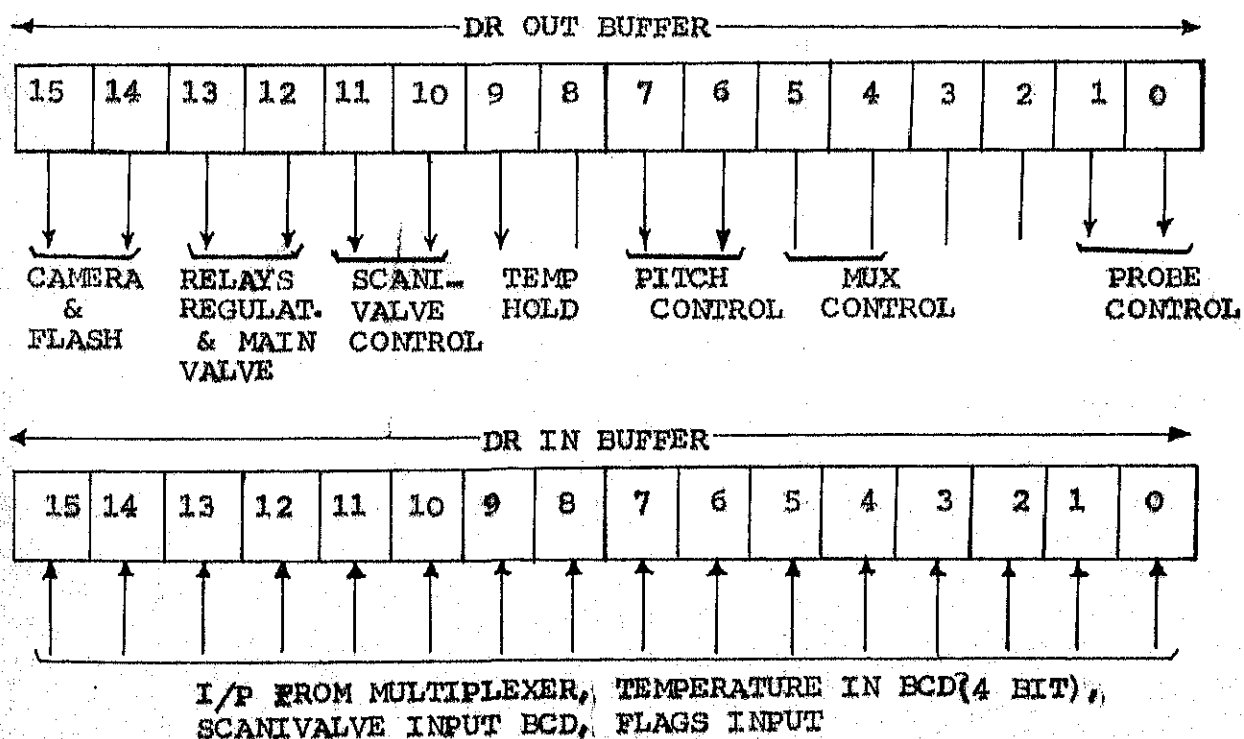
APPENDIX A Fig. 1.2   BIT UTILISATION DETAILS OF 16 BIT PARL. I/O

DROU8F

CONTROL BIT 04 FOR MUX.

74157

74157

74157

74157
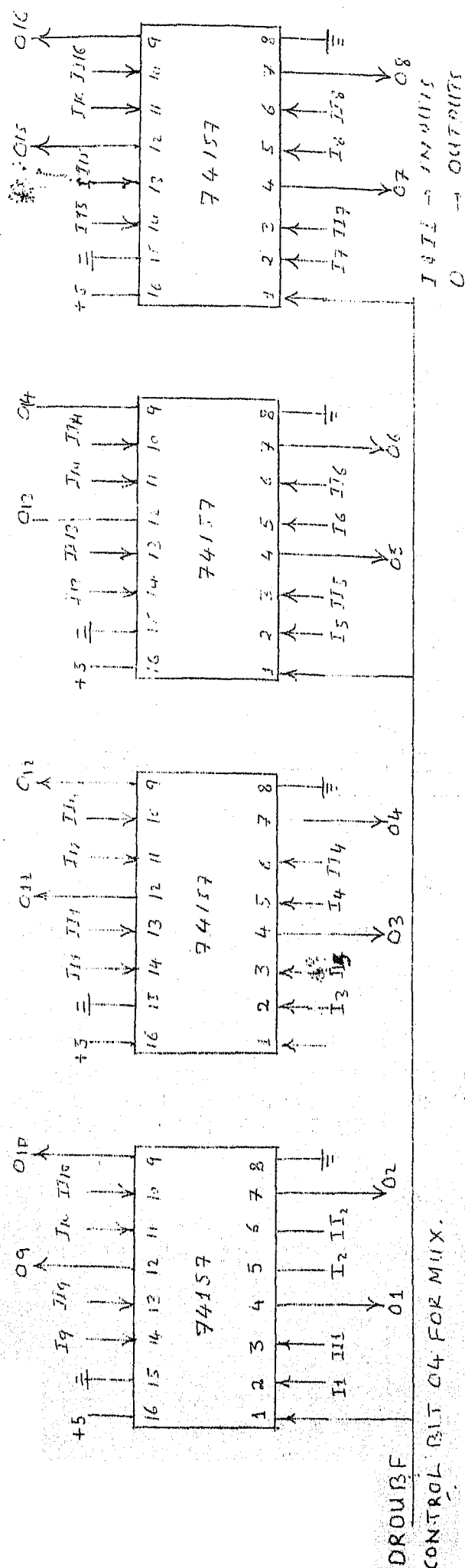
32 BITS INPUT 16 BITS OUTPUT MUX TO DRINBF

$I \& II \rightarrow INPUTS$

$O \rightarrow OUTPUTS$

16 LINES INPUT   16 LINES INPUT   16 LINES I/P   SPARE
TEMP MODULE   SCANIVALVE   CHECK
                                  FLAGS

MUX 64 INPUT LINE 16 OUTPUT LINES

DROU8F
BIT04,05
MUX CONTROL

DRINBUFFER PDP 11/03
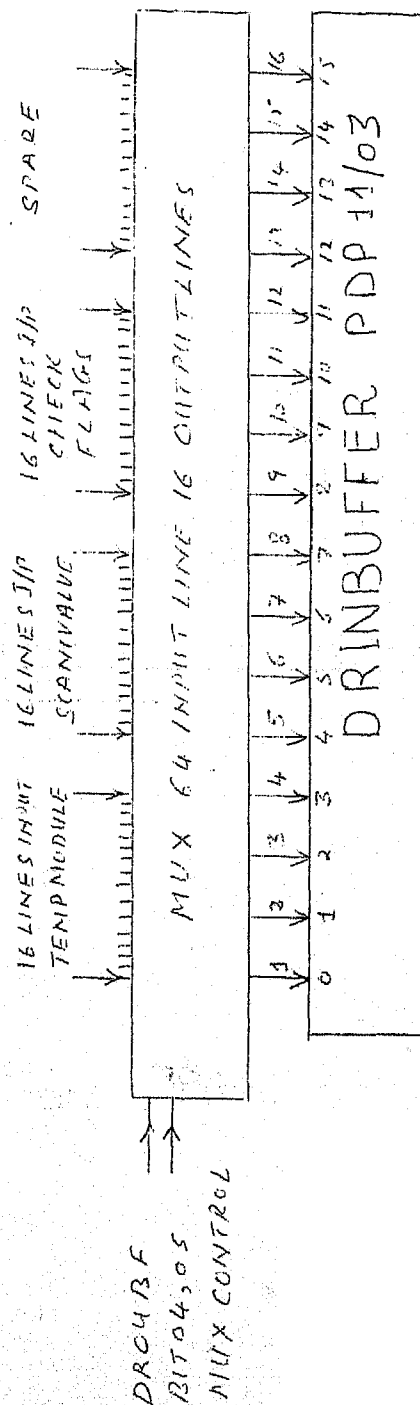
MUX DETAILS TO INCLUDE AUTOMATIC FLAG CHECK

FIG. 1, 2 APPENDIX "A".

INPUTS OF SUBSYSTEMS READINESS

PROBE GEAR · · · PITCH GEAR · CALIB. SYSTEM · ANP. TEMP. MODULE · SCANI VALVE · MAIN VALVE · REG. VALVE · FLASH · CAMERA

+5V

16 BIT FLAG INPUTS TO 64/16 LINES MUX

APD A. FIG.4 AUTOMATIC FLAG CHECK SCHEMIETA

```
                    COLD
                    START
                      │
                      ▼
                 ┌──────────┐
                 │ BOOTSTRAP│
                 └──────────┘
                      │
                      ▼
                 ┌──────────┐
                 │ RMON SJ  │
                 └──────────┘
                      │
                      ▼
                 ┌──────────┐
                 │ USR  KMON│
                 └──────────┘
                      │
                      ▼
            ┌────────────────────┐
            │ ENTER DATE, TIME   │
            │ EXP NO. MACH NO.   │
            │  MOD. NO. TYPE     │
            └────────────────────┘
                      │
                      ▼
            ┌────────────────────┐
            │  R. WIND.T. EXP.   │
            └────────────────────┘
                      │
                      ▼
            ┌────────────────────┐
            │   CONV. ROUTINE    │
            │ ENTER EXP TIME     │
            │ NO. OF READINGS    │
            │ NO. OF EXPOSURES   │
            │ ROLL, PITCH DETAILS│
            └────────────────────┘
```

COLD START

BOOTSTRAP

RMON SJ

USR KMON

ENTER DATE, TIME EXP NO. MACH NO. MOD. NO. TYPE

R. WIND.T. EXP.

CONV. ROUTINE
ENTER EXP TIME
NO. OF READINGS
NO. OF EXPOSURES
ROLL, PITCH DETAILS

ALL SUB.SYS RDY?   YES   NO WAIT

CALL CALIBERATION STORE DATA

CHECK SYS READINGS?   NO WAIT   YES   READY TO GO

FIX INITIAL SETTINGS CALL PROBE, PITCH CALL ROLL

ALL DONE?   NO   YES

CALL FEEDBACK AND COMPARE

ERROR MAG ON?   NO   YES

CALCULATE ERROR NO. OF PULSES/DIR

OV

FIG. 2 – EXP FLOW CHART

OV → OPEN ISOLATOR VALVE → FULLY OPEN? → (NO → WAIT) / (YES) → OPEN REG. VALVE → COUNT DOWN 10 SEC STAB. → START PROG. CLOCK FOR TIME INT. I → CALL READS STORE IN CORE → ANY MORE READINGS? → (YES) → (NO) → COLLECT DATA FROM SCANNY V. → CARRY OUT TEMP. PRES. CORR. → STORE DATA IN DISK PRINT OUT/DISPLAY → STOP END

I → TIME FOR SCANNY VALVE? → (NO) / (YES) → ORDER INITIATE PORT LOCK UP → IS CAMERA FLAG ON? → (NO) / (YES) → CLEAR FLAG CALL CAMERA CALL FLASH CALCULATE NEXT FLAG → FIX NEW SETTINGS CALL PROBE CALL ROLL CALL PITCH → ALL DONE? → (NO) / (YES) → CALL FEEDBACK CALCULATE ERROR → ERRPR FLAG ON? → (YES → CALCULATE PULSES/DIR) / (NO → WAIT FOR INT I)

Sp2.R : EXP FLOW CHART

APPENDIX C

```
// FOR ROTS
*IOCS (CARD,TYPEWRITER,DISK,KEYBOARD)
*ONE WORD INTEGERS
        EXTERNAL GEN
        COMMON/INSKEL/I11,N11,K11,IPOSE(3),L11,CALO1,CALO2
        COMMON IC(100),M(10),N(25),IFLAG,IDATA(3)
        DEFINE FILE 1(100,1.U.ICE)
C       CALO1 IS THE READING OF AMP. ZERO OFFSET
C       CALO2 IS THE AMP. GAIN
C       CALO3 IS THE UNCORRECTED AMP. ANALOG INPUT READING
C       IKAM ARE THE TABLE VALUES FOR DO FOR CONTACT OPERATE
        IKAM(3)=2
C       121 IS THE CO ADDRESS
        IKAM(2)=127
C       IKAM(1)=0 IS DONE FOR INETIALIZATION
        IKAM(1)=0
C       IPOSE ARE THE TABLE VALUES FOR POSITION DO
        IPOSE(3)=2
C       IPOSE 2)=121 GIVES THE DO ADDRESS
        IPOSE(2)=121
C       IPOSE(1)=0 IS FOR INETIALIZING
        IPOSE(1)=0
        N11=1
        K11=1
        L11=1
        CALL UNMK(-1,-1)
        CALL CON
        CALL CAL
        CALL PIT
C       DELAY PORTION
C       THIS PORTION GIVES 10 SECONDS DELAY AFTER REGULATOR
        VALVE HAS BEEN OPEND THEN THE EXPRIMENT  STARTS
        WRITE(1,300)
300     FORMAT(//.#OPEN ISOLATOR VALVE WAIT FOR FULL ON
        INDICATION#,//)
        CALL BUSY
        WRITE(1,10)
10      FORMAT(#WIND TUNNEL DATA ACQUSITION EXP STARTS#,//,#
        PRESS START#)
        CALL BUSY
        PAUSE 124
        WRITE (1,310)
310     FORMAT(1H,#OPEN REG. VALVE THERE WILL BE 10 SEC. DELAY
        TO START#)
        CALL BUSY
        CALL DELAY (500,200)
```

```
C          CONTACT OPERATE INETIALIZATION
           CALL CO(11001, IKAM(1). IKAM(3))
C          POSITION DO INETIALIZATION
           CALL DO(11001, IPOSE(1), IPOSE(3))
C          SETTING FOR BIT 01=1 AND 00=1 FOR FORWARD DIRECTION
           IPOSE(1)=3
C          IFLAG=1 IS FOR FORWARD DIRECTION
           IFLAG=1
C          START TIME RECORD
           CALL CLOCK(I)
           I11=I
           CALL TIMER (GEN,2,1000)
15         IF(LD(5))15,20,20
20         CONTINUE
           CALL VIAQ
           END
// FOR ROT3
           SUBROUTINE DELAY(M.N)
C          THIS ROUTINE GIVES REQUIRED DELAY FOR THE CORRECT
C          WIDTHS OF THE PULSES REQUIRED BY THE STEPPER MOTOR SYSTEM
           DO 500 J=1,M
           DO 500 K=1,N
500        CONTINUE
           RETURN
           END
// FOR ROT4
           SUBROUTINE GEN
C          ROUTINE GEN IS THE ROUTINE WHICH CALLS LEVEL 8 ROUTINE
           IN TIMER
           CALL LEVEL (8)
           RETURN
           END
// FOR ROT5
           SUBROUTINE CON
C          THIS ROUTINE INSURES VARIOUS DATA ENTRY AND SUB SYSTEM
C          READYNESS CONVERSATION ROUTINE AND DATA ENTRY
C          DATA TAKEN AS FOLLOWS
C          ENTER NO OF PROBE READINGS IN ONE DIRECTION ------
C          NO OF TOTAL PROBE READINGS -------------------------
C          ENTER NO OF ANALOG READINGS OF INPUT
C          ENTER NO OF CAMERA SHOTS
C          ENTER PITCH (INETIAL) ANGLE------DEG.TAKE OFF
           WRITE(1.111)
111        FORMAT(#********** *********************************
```

```
              CALL BUSY
              WRITE(1,112)
112           FORMAT(//,#WIND TUNEL EXPERIMENTAL SETUP DATA
               ENTRY ROUTINES#)
              CALL BUSY
              WRITE(1,116)
116           FORMAT(/,#PLEASE ENTER DATA THROUGH KEY.B/CONSOLE BOARD#)
              CALL BUSY
              WRITE (1,113)
113           FORMAT(/,#ENTER NO OF PROBE READINGS-------40#)
              CALL BUSY
              READ (2,223)IX
223           FORMAT (I2)
              WRITE(1,114)
114           FORMAT(/,#ENTER NO OF CAMERA READINGS----20#)
              CALL BUSY
              READ(2,223)IX
              WRITE(1,115)
115           FORMAT(/,#ENTER INETIAL AIRCRAFT PITCH---15 DEG.TAKE OFF#)
              CALL BUSY
              READ(2,223)IX
              WRITE(1,111)
              CALL BUSY
              WRITE(1,101)
101           FORMAT(//,#ANSWER 1 FOR YES,ANY OTHER NO FOR NO#,/)
              CALL BUSY
200           WRITE(1,201)
201           FORMAT(#IS CAMERA ON#,/)
              CALL BUSY
              READ(2,11)IA1
11            FORMAT(I1)
              IF(IA1-1)300,12,300
300           WRITE(1,91)
91            FORMAT(1H,#SWITCH ON CAMERA SYSTEM#,/)
              CALL BUSY
              GO TO 200
12            WRITE(1,210)
210           FORMAT(1H,#IS AMPLIFIER ON#,/)
              CALL BUSY
              READ(2,11)IA2
              IF(IA2-1)400,13,400
400           WRITE(1,92)
92            FORMAT(1H,#SWITCH ON THE AMP SYSTEM AND LET IT
               STABLIZE#,/)
              CALL BUSY
              GO TO 12
13            WRITE(1,220)
```

```
220        FORMAT(1H.#IS PROBE DRIVE SYSTEM ON#,/)
           CALL BUSY
           READ(2,11)IA3
           IF(IA3-1)500,14,500
500        WRITE(1,93)
93         FORMAT(1H.#SWITCH ON THE PROBE DRIVE SYSTEM#,/)
           CALL BUSY
           GO TO 13
14         WRITE(1,230)
230        FORMAT(1H,#IS SCANNY VALVE SYSTEM ON#,/)
           CALL BUSY
           READ(2,11)IA4
           IF(IA4-1)600,15,600
600        WRITE(1,94)
94         FORMAT(1H,#SWITCH ON THE SCANNY VALVE SYSTEM#,/)
           CALL BUSY
           GO TO 14
15         WRITE(1,240)
240        FORMAT(1H,#IS PITCH DRIVE SYSTEM ON#,/)
           CALL BUSY
           READ(2,11)IA5
           IF(IA5-1)700,16,700
700        WRITE(1,95)
95         FORMAT(1H,#SWITCH ON PITCH DRIVE SYSTEM#,/)
           CALL BUSY
           GO TO 15
16         CONTINUE
           RETURN
           END
// FOR ROT6
           SUBROUTINE PIT
C          THIS ROUTINE FIXES THE PITCH OF THE AIRCRAFT
           DIMENSION IDATA(3)
           WRITE(1,1)
1          FORMAT(//,#AIRCRAFT INETIAL PITCH BEING SET TO
          15 DEGREES#)
           CALL BUSY
C          PITCH TAKEN HERE IS 15 DEGREES TAKEOFF
           IDATA(3)=2
           IDATA(2)=120
           IDATA(1)=0
           DO 17 I=1,10
           IDATA(1)=0
           CALL DO(11001,IDATA(1),IDATA(3))
33         CALL DO(0,ITST1)
           CALL DELAY(5,5)
           GO TO (33,34),ITST1
```

```
34         CONTINUE
           IDATA(1)=3
           CALL DO(11001,IDATA(1).IDATA(3))
CALL DELAY(10.10)
35         CALL DO(0.ITST1)
           GO TO (35,36),ITST1
36         CONTINUE
17         CONTINUE
           RETURN
           END
//FOR ROT7
           SUBROUTINE CALL
C          THIS ROUTINE IS USED TO CALIBERATE THE AMPLIFIERS AND
C          TO CALCULATE THE ZERO OFFSET WHICH IS USED TO
           CORRECT ANALOG READINGS
1          WRITE(1,1)
1          FORMAT(//,#GIVE ZERO INPUT TO THE AMPLIFIER#)
           CALL BUSY
           WRITE(1,2)
2          FORMAT(//,#ONCE ZERO INPUT GIVEN PRESS START#,//)
           CALL BUSY
           PAUSE129
           CALL AIP(01000,CAL01.4108)
4          CALL AIP(0,ITST2)
           GO TO(4,5),ITST2
5          CONTINUE
           WRITE(1.6)
6          FORMAT(//,#GIVE UNIT INPUT VOLTAGE TO AMP TO
           CALC. GAIN#,//)
           WRITE(1,7)
7          FORMAT(#PRESS START#,//)
           CALL BUSY
           PAUSE 126
           CALL AIP(01000,CAL02.4108)
8          CALL AIP(0,ITST2)
           GO TO (8,9),ITST2
9          CONTINUE
           RETURN
           END
*STORECI M       ROT1   ROTS    ROT1
*FILES(1,FILE1,0)
*CCEND

// JOB
// DUP
// FOR ROTSS
*IOCS(TYPEWRITER,DISK)
*ONE WORD INTEGERS
```

```
            INTEGER CALO3
            REAL X
            EXTERNAL GEN
            COMMON/INSKEL/111,N11,K11,IPOSE(3).IKAM(3),L11,CALO1,
           C ALO2
            COMMON IC(100),M(10),N(25),IFLAG,IDATA(3)
            DEFINE FILE 1(100,1.U,I3)
            DO 98 I=1.10
            CALL DO(11001,IPOSE(1),IPOSE(3))
94          CALL DELAY(5,20)
94          CALL DO(0,ITST1)
            GO TO(94,96),ITST1
96          IF(2-IFLAG)101,101,102
102         IPOSE(1)=2
            GO TO 103
101         IPOSE(1)=0
            CALL DO(11001,IPOSE(1),IPOSE(3))
            IPOSE(1)=1
            GO TO 97
103         CALL DO(11001,IPOSE(1),IPOSE(3))
            IPOSE(1)=3
97          CALL DO(0,ITST1)
            GO TO(97,98),ITST1
98          CONTINUE
            CALL CLOCK(I)
            IC(L11)=1
            CALL AIP(01000,CALO3,4108)
111         CALL AIP(0,ITST2)
            GO TO (111,112),ITST2
112         L11=L11+1
            IC(L11)=CALO3-CALO1
            IF(20-N11)330,552,340
340         IPOSE(1)=3
            IFLAG=1
            GO TO 341
52          WRITE(1,551)
551         FORMAT(/,/*****REVERSE DIRECTION MOVEMENT****#,/)
            CALL BUSY
330         FLAG=2
            IPOSE(1)=1
341         K2=2*K11
            IF(K2-N11)600,410,420
410         IKAM(1)=2
            CALL CO(11001,IKAM(1),IKAM(3))
222         CALL CO(0,ITST3)
            GO TO (222,223),ITST3
223         IKAM(1)=0
```

```
        CALL CLOCK(I)
        L11=L11+1
        IC(L11)=I
        K11=K11+1
        IF(40-N11)600,600,420
420     N11=N11+1
        L11=L11+1
        CALL DELAY(20,20)
        CALL CO(110011,IKAM(1),IKAM(3))
        CALL TIMER(GEN,2,1000)
77      IF(LD(5))77,78,78
78      CALL INTEX
600     CALL CLOCK(I)
        I12=I-111
        WRITE(1,14)I11,I12
14      FORMAT(1H,#START TIME#,15,#  FINISH TIME#,15,//)
        CALL BUSY
        WRITE(1,16)
16      FORMAT(#  PTIME#,#  ANALOG IP #,# FTIME#,//)
        CALL BUSY
        J1=1
        JJ=1
33      GO TO(18,19),JJ
18      IC1=IC(J1)
        J1=J1+1
        IC2=IC(J1)
        X=IC2
        X=(X*5.5)/32768
        WRITE(1,21)IC1,X
21      FORMAT(15,3X,F9,5)
        CALL BUSY
        JJ=2
        GO TO 99
19      IC1=IC(J1)
        J1=J1+1
        IC2=IC(J1)
        X=IC2
        X=(X*5.0)/32768
        J1=J1+1
        IC3=IC(J1)
        WRITE(1,22)IC1,X,IC3
22      FORMAT(15,3X,F9,3X,16)
        CALL BUSY
        JJ=1
99      IF(100-J1)114,114,113
113     J1=J1+1
        GO TO 33
```

```
114        WRITE(1,23)
23         FORMAT(//,#STORING OF DATA ON DISKO FILE1 STARTS#,//)
           CALL BUSY
           DO 555 J1=1,100
           WRITE(1#1)IC
555        CONTINUE
           WRITE(1,25)
25         FORMAT(#****EXPERIMENT OVER DATA IS SAFELY TUCKED
           IN DISK*****#)
           CALL BUSY
           CALL INTEX
           END
//FOR ROT3
           SUBROUTINE GEN
           CALL LEVEL (8)
           RETURN
           END
//FOR ROTT
           SUBROUTINE DELAY(M,N)
           DO 500 J=1,M
           DO 500 K=1,N
500        CONTINUE
           RETURN
           END
//DUP
*STORECI  I     R1      ROTSS ROT1
*FILES(1,FILE1,0)
*CCEND
//DUP
```

APPENDIX D

```
     WINDTL.BAS
5  REM-*******************************************************
10 REM-WINDTUNNEL DATA ACQUSITION AND CONTROL SYSTEM ROUTINES
15 REM-
20 REM-BEGINNING OF CONVERSATION AND DATA ENTRY ROUTINES
25 DIM A1(50),A2(50),A3(50)
30 PRINT "WELCOME TO TRISONIC WINDTUNNEL SYSTEM OF AERO ENGG"
35 PRINT "              DEPT. OF I.I.T.K.
40 REM-
50 PRINT "PLEASE FOLLOW THE INSTRUCTIONS CORRECTLY"
60 PRINT
70 PRINT "PLEASE ENTER ON CONSOLE DATE,EXP.NO.,MACH NO.,MOD.NO".
80 PRINT
90 PRINT "DATE? DD-MM-YY(EG.05-MAY-78)"
100 INPUT A1$
110 PRINT "EXPERIMENT NO"
120 INPUT A2$
130 PRINT "MACH NO."
140 INPUT A3$
150 PRINT "EXPERIMENT DONE BY"
160 INPUT A4$
170 PRINT
180 PRINT "PLEASE ENTER EXPERIMENT PARAMETERS"
190 PRINT
200 PRINT "DURATION OF THE EXPERIMENT IN SECOND (INTEGER)"
210 INPUT N1
220 PRINT
230 PRINT "TOTAL NUMBER OF PROBE
240 INPUT N2
245 PRINT
250 PRINT "NUMBER OF TEMPERATURE PROBE READINGS" .
260 INPUT N4
265 PRINT
270 PRINT "NUMBER OF CAMERA SHOTS"
280 INPUT N5
290 PRINT
300 PRINT "INITIAL PITCH IN STEPS(1 STEP=1.8 DEGREES)"
310 INPUT N6
320 PRINT
330 PRINT "INCREMENTAL PITCH STEPS-O FOR NO CHANGE"
335 INPUT N7 ************************************************
340 REM-*******************************************************
345 REM-
350 REM-SUBASSEMBLIES CHECK ROUTINES
360 REM-THESE ROUTINES ARE TEMPORARY AND WILL BE REPLACED BY
```

```
370 REM-AUTOMATIC FLAG CHECKS
380 PRINT
390 PRINT "PLEASE ANSWER Y OR N FOR YES OR NO"
400 LET B1$="Y"    B2$="N"
410 PRINT
420 PRINT "IS DC POWER SUPPLY SYSTEM ON"
430 INPUT C$
440 IF C$=B1$ THEN 480
450 IF C$=B2$ THEN 470
460 PRINT
465 PRINT "PLEASE TYPE Y OR N"
470 PRINT "PLEASE SWITCH ON DC SUPPLY" \ GO TO 420
480 PRINT
490 PRINT "IS SCANIVALVE SUB SYSTEM READY"
500 INPUT C$
510 IF C$=B1$ THEN 560
520 PRINT
525 PRINT "DO YOU NEED SCANIVALVE IN THIS RUN
530 INPUT C$
540 IF C$=B2$ THEN 560
550 PRINT "PLEASE SWITCH ON SCANIVALVE SUB SYSTEM" \ GO TO 490
560 PRINT
565 PRINT "PRINT "IS PROBE DEIVE SUBSYSTEM READY"
570 INPUT C$
580 IF C$=B1$ THEN  640
590 PRINT
600 "DO YOU WANT THE PROBE MOVEMENT"
610 INPUT C$
620 IF C$=B2$ THEN 640
630 PRINT
635 PRINT "PLEASE SWITCH ON PROBE DRIVE SUBSYSTEM" \ GO TO 565
640 PRINT
645 PRINT "IS MODEL ATTITUDE GEAR SYSTEM READY"
680 INPUT C$
690 IF C$=B1$ THEN 720
700 PRINT
710 PRINT "PLEASE SWITCH ON THE PITCH DRIVE SUBSYSTEM" GO TO 645
720 PRINT
725 PRINT "IS CALIBRATION SUBSYSTEM READY"
730 INPUT C$
740 IF C$=B1$ THEN 760
750 PRINT
755 PRINT "PLEASE SWITCH ON CALIBRATION SYS.FOR STAB." GO TO 725
760 PRINT
765 PRINT "IS ANALOG SUBSYSTEM READY"
```

```
770 INPUT C$
780 IF C$=B1$ THEN 800
795 PRINT "PLEASE SWITCH ON ANALOG SUBSYSTEM"  GO TO 765
800 PRINT
810 PRINT "IS CAMERA/FLASH SUB SYSTEM READY? PLEASE SET  APER-"
815 PRINT "TURE,SPEED, AUTO,NO OF FRAMES"
820 INPUT C$
825 IF C$=B1$ THEN 880
830 PRINT
835 PRINT "DO YOU WANT SNAPS TO BE TAKEN"
840 INPUT C$
850 IF C$=B2$ THEN 880
860 PRINT "PLEASE SWITCH ON CAMERA/FLASH SUB SYS,ADJUSTMENTS"
865 GO TO 810
868 REM-********************************************************
869 REM-
870 REM-BEGINNING OF CALIBRATION ROUTINE
880 PRINT
890 PRINT "YOU NEED ADJUSTING ZERO OFFSET OF PROBE AMP."
895 PRINT "PLEASE DISCONNECT PROBE INPUT TO AMP.,FEED ZERO TO"
900 PRINT "AMP INPUT ADJUST ZERO OFFSET FOR ZERO O/P"
910 PRINT "WHEN FINISHED TYPE OK ON TERMINAL"
920 LET E$="OK"
930 INPUT C$
940 IF C$=E$ THEN 950
945 GO TO 890
950 PRINT "PLEASE FEED UNIT INPUT TO ADD INPUT SAY OK WHEN DONE"
960 INPUT C$
970 IF C$=E$ THEN 980
975 GO TO 950
980 CALL "ADC" (0,G1)
990 PRINT "PLEASE NOW FEED UNIT INPUT TO AMP AND CONNECT O/P TO"
995 PRINT "ADC OF 11/03, SAY OK WHEN DONE"
1000 INPUT C$
1010 IF C$=E$ THEN 1020
1015 GO TO 990
1020 CALL "ADC" (0,G2)
1040 G=G2/G1
1050 PRINT
1055 REM-********************************************************
1058 REM-FINAL CHECK,PARAMETER CALC.,INITIAL FIXATION ROUTINES
1060 PRINT "IS SYSTEM READY IN ALL RESPECTS TO START"
1070 INPUT C$
1080 IF C$=B1$ THEN 1115
1090 GO TO 1060
1110 PRINT
1115 PRINT "FIX MODEL & PROBE TO INITIAL ZERO REF POINT,TYPE OK"
```

```
1120 INPUT C$
1130 IF C$=E$ THEN 1150
1140 GO TO 1110
1150 T=(N1/N2)*100000
1155 T=INT(T)
1160 N3=INT(200/N2)
1165 REM-N3 IS THE NO OF STEPS TO BE MOVED BY PROBE AT A TIME
1170 IF N3 <=20 THEN 1180
1175 N9=1
1180 IF N6 >=0 THEN 1200
1190 B=1   GO TO 1400
1200 B=0
1300 REM-INITIAL SETTING OF MODEL ATTITUDE IS TO BE DONE
1400 CALL "PITH" (N6,B)
1420 REM-
1430 REM-************************************************
1440 REM-
1450 REM-BEGINING OF CONTROL AND ACQUISITION ROUTINES
1500 PRINT
1600 PRINT "THE EXPERIMENT WILL NOW BEGIN WITH OPENING OF
     MAIN VALVE"
1610 PRINT "FOLLOWED BY REGULATOR VALVE AFTER SENSING FULL OPEN"
1620 PRINT "FLAG, THEIS IS FOLLOWED BY 10 SECONDS OF STABLE.."
1630 PRINT "ISATION DELAY AND THERE AFTER THE EXPERIMENT"
1700 CALL "VALV"
1800 CALL "SETC" (5,10)
1900 CALL "WAIT" (0)
2000 I=0 \ I1=1
2050 CALL "SETR" (2,0,T)
2100 FOR N=1 TO N2
2200 I=I+1 \ I1=I1+1
2300 CALL "ADC" (0,C)
2350 A1(N)=C
2400 CALL "TEMP" (C)
2450 A2(N)=C
2600 IF N=1 THEN 3000
2700 IF N9=1 THEN 3000
2800 IF I< 3 THEN 3100
2900 I=1
3000 CALL "CAMR"
3100 IF N< 21 THEN 3300
3200 B=1
3300 CALL "PROB" (N3,B)
3400 IF N=20 THEN 3600
3500 GO TO 4000
```

```
3600 CALL "SCAN" (0,C)
3700 IF N7=0 THEN 4200
3800 B=1
3900 CALL "PITH" (10,B)
4000 IF I1 < 3 THEN 4200
4100 CALL "PITH" (N7,B)
4150 I1=1
4200 CALL "WAIT" (0)
4300 NEXT N
4400 REM-****************************************************
4450 REM DATA COLLECTION/CONVERSION ROUTINES
4500 PRINT
4550 PRINT "EXPERIMENT IS OVER,SCANIVALVE DATA COLLECTION,CONV"
4560 PRINT "ERSION OF TEMP.BCD DATA STARTS"
4600 REM-****************************************************
4700 REM-SCANIVALVE COLLECTION AND CONVERSION ROUTINE
4750 FOR N=1 TO 48
4800 A7=0 \ A8=1
5000 CALL "SCAN" (1,C)
5100 A4=C
5150 A3(N)=0
5200 IF A4=0 THEN 6000
5300 A5=INT(A4/16)
5400 A6=A4-(A5*16)
5500 A7=A7+(A6*A8)
5600 IF A5=0 THEN 5900
5700 A8=A8*10
5800 A4=A5  GO TO 5300
5900 A3(N)=A7
6000 NEXT  N
6025 REM-****************************************************
6050 REM-TEMPERATURE BCD TO DECIMAL DATA CONVERSION
6100 FOR N=1 TO N2
6200 A7=0   A8=1
6400 A4=A2(N)
6500 IF A4=0 THEN 7200
6600 A5=INT (A4/16)
6700 A6=A4-(A5*16)
6750 A7=A7+(A6*A8)
6800 IF A5=0 THEN 7100
6900 A8=A8*10
```

```
7000  A4=A5  GO TO 6600
7100  A2(N) = A7
7200  NEXT N
7300  PRINT
7400  PRINT
7450  PRINT A1$
7460  PRINT A2$
7470  PRINT A3$
7480  PRINT A4$
7490  PRINT
7500  PRINT "S.NO.    PRESS.    TEMP    SCAN1.PR"
7600  FOR I=1 TO 50
7700  PRINT 1,A1(1),A2(1),A3(1)
7750  NEXT 1
7800  END
*
```

```
=FUN4.MAC

FUNA-ASSEMBLY FUNCTIONS
            . TITLE FUN4
            . GLUBLE VALVFN, FRUBFN, PITHFN, CAMRFN
            . GLUBL TEMPFN, INT, STORE


RO=ZO    %0
R1=Z1    %1
R2=Z2    %2
R3=Z3    %3
R4=Z4    %4
R5=Z5    %5
SP=Z6    %6
PC=Z7    %7
OUBF=167772
INBF=167774
DRCSR=167770
FAC1= 40
FAC2= 42
;"VALV"
VALVFN:  CLR OUBF
         BIS #010000, OUBF
   X1:    TSTB    DRCSR
         BPL    X1
   X2:    BIS #020000, OUBF
         RTS PC
;"CAMR"
CAMRFN:  CLR OUBF
         MOV #20000, R2
         BIS #140000,OUBF
         RTS PC
;"PITH" (A,B)
PITHFN:  CLR OUBF
         MOV #TABLE, RO
         JSR PC, GETARG
         .BYTE 1,1,0
         .EVEN

         MOV A1,FAC1, (R5)
         MOV A2,FAC2 ( R5)
         JSR PC, INT
         MOV FAC2 (R5),R2
         MOV B1, FAC1 (R5)
         MOV B2, FAC2 (R5)
```

```
                JSR  PC,  INT
                MOV  FAC2 (R5), R3
X4:             MOV  #750,R4
X5:             TSTB R2
                BEQ  X21
                TSTB R3
                BEQ  X6
                BIS  #0003000, OUBF
                BR   X7
X6:             BIS  #000100, OUBF
X7:             DEC  R4
                TST  R4
                BNE  X7
                CLR  OUBF
                MOV  #250,R4
X8:             DEC  R4
                TST  R4
                BNE  X8
                DEC  R2
                BPL  X4
X21:            RTS  PC


;"PROB"  (A,B)
PROBFN:  MOV  #TABLE,RO
                JSR  PC, GETARG
                .BYTE 1,1,0
                .EVEN
                MOV  A1,FAC1 (R5)
                MOV  A2, FAC2 (R5)
                JSR  PC, INT
                MOV  FAC2 (R5), R2
                MOV  B1, FAC1 (R5)
                MOV  B2, FAC2 (R5)
                JSR  PC, INT
                MOV  FAC2 (R5),R3
                CLR  OUBF

X9:             MOV  #750,R4
                TSTB R2
                BEQ     X20
X10:            TSTB R3
                BIS  #000003, OUBF
                BR   X12
X11:            BIS  #000001, OUBF
X12:            DEC  R4
                TST  R4
                BNE  X12
```

```
            CLR OUBF
            MOV #250,R4
X13:        DEC R4
            TST R4
            BNE X13

X14:        DEC R2
            BPL X9
            CLR OUBF
X20:        RTS PC

;"TEMP"(C)
TEMPFN:CLR OUBF
            MOV #TABLE, RO
            JSR PC, GETARG
            .BYTE 2,0
            .EVEN
            BIS #001000, OUBF

            CLR FAC1 (R5)
            MOV INBF, FAC2 (R5)
            MOV #A1, RO
            JSR PC, STORE
            CLR OUBF
            RTS PC

;"SCAN" (A,C)
SCANFN: MOV #TABLE, RO
            JSR PC, GETARG
            .BYTE 1,2,0
            .EVEN
            MOV A1,FAC1 (R5)
            MOV A2,FAC2 (R5)
            JSR PC, INT
            MOV FAC2 (R5), R2
            TSTB R2
            BNE X15
            CLR FAC1 (R5)
            CLR  OUBF
            BIS #002000, OUBF
            MOV INBF, FAC2 (R5)
            MOV #B1, RO
            JSR PC, STORE
            BR       X16
X15:        BIS #004000, OUBF
X16:        RTS PC
```

```
TABLE:

        A1:.WORD 0
        A2:.WORD 0
        B1:.WORD 0
        B2:.WORD 0
        C :.WORD 0
                    .END

    FUN3.MAC

        .GLOBL VALVFN, PRUBFN, PITHFN,SCANFN, TEMPFN
        .CSECT BASICR
        .WORD FUNTAB
        .CSECT FUN1
FUNTAB: .ASCII 'VALV'
        .WORD VALVFN
        .ASCII 'PRUB'
        .WORD PRUBFN
        .ASCII 'PITH'
        .WORD PITHFN
        .ASCII 'CAMR'
        .WORD CAMRFN
        .ASCII 'SCAN'
        .WORD SCANFN
        .ASCII 'TEMP'
        .WORD TEMPFN
    .END
```

APPENDIX E

```
22-JUL-78
MONITR.SYS    46   3-JUL-78
DXMNFB.SYS    58   3-JUL-78
TT    .SYS     2   6-JAN-77
DX    .SYS     2   6-JAN-77
RK    .SYS     2   6-JAN-77
PIP   .SAV    14   6-JAN-77
MACRO .SAV    31   6-JAN-77
EDIT  .SAV    19   6-JAN-77
LINK  .SAV    25   6-JAN-77
SYSMAL.SML    18   16-APR-78
PATCH .SAV     5   23-JUN-78
BASIC .SAV    39   24-JUN-78
BASLPS.SAV    43   22-JUL-78
WINDTL.BAS    14   22-JUL-78
FUN4  .MAC     4   22-JUL-78
FTBL  .MAC     7   22-JUL-78
PERPAR.MAC     2   22-JUL-78
PERVEC.MAC     4   22-JUL-78
RTINT .MAC     1   22-JUL-78
FPMP  .OBJ     8   22-JUL-78
GETARG.MAC     5   22-JUL-78
LPS0  .OBJ     4   22-JUL-78
LPS1  .OBJ     4   22-JUL-78
LPS2C .OBJ     4   22-JUL-78
LPS3  .OBJ     4   22-JUL-78
LPS   .OBJ     5   22-JUL-78
BASICE.OBJ    17   22-JUL-78
BASICR.OBJ    11   22-JUL-78
BASICX.OBJ    19   22-JUL-78
BASICH.OBJ     9   22-JUL-78
  UNUSED       2
30 FILES, 426 BLOCKS
   2 FREE BLOCKS
```

REFERENCES

1. Cooper J.W., Minicromputer in the Laboratory., Wiley-Interscience Publication, John Wiley & Sons. New York.

2. DEC. Microprocessor Hand Book, Digital 1977-78. Digital Equipment Corporation, Mass, U.S.A.

3. DEC. PDP-11 Peripherals Hand Book, Digital 1976-77. Digital Equipment Corporation, Mass, U.S.A.

4. DEC. PDP-11/03,11/05,11/35 Processor Hand Book, Digital 1977 Digital Equipment Corporation Mass, U.S.A.

5. DEC. RT-11 System Reference Manual, DEC-11-ORUGA-A.D.-1976 Digital Equipment Corporation Mass, U.S.A.

6. DEC. SOFTWARE Manual, Digital 1977, Digital Corp Equipment Corporation, Mass, U.S.A.

7. DEC. SYSTEM Reference Manual (PDP-11), Digital 1975. Digital Equipment Corporation.

8. DEC. Users Manual ADVII-A, KWVII-A, DRV-11, EK-ADVI-OP-002-77 Digital Equipment Corporation, Mass, U.S.A.

9. Heron I.C. WRE, Report-148 (WR&D) and 784 (WR&D) Australian Defence Scientific Service Adelaids. S. Austrialia.

10. IBM Time Sharing Executive System Concepts and Technique. 1800-36(GC26-3703-1). IBM Corporation, Programming Publication. CA, U.S.A.

11. MALVINO & LEACH Digital Principles, Prentice Hall.

12. RAJARAMAN, An Introduction to Digital Computer Design. Prentice Hall.

13. Southern R.W. PDP-11 Programming Fundamentals Adgonquin College Book Store OTTAWA, Canada.